Final Environmental Impact Statement

Volume 2 of 2 Appendices A through O

Kaneohe/Kailua Wastewater Conveyance and Treatment Facilities

Prepared For:

CITY AND COUNTY OF HONOLULU
DEPARTMENT OF ENVIRONMENTAL SERVICES

Prepared By:

WILSON OKAMOTO CORPORATION

May 2011

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Volume 2 of 2 – Appendices A through O

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District of Koolaupoko, Island of Oahu

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AECOS, Inc.
December 2010

Biological surveys of marine resources in south Kāneʻohe Bay along two corridors proposed for subterranean pipelines.

December 3, 2010 *AECOS* No. 1215C

Steve Coles, Chad Linebaugh, and Katie Laing
AECOS, Inc.
45-939 Kamehameha Hwy, Suite 104
Kāne'ohe, Hawai'i 96744
Phone: (808) 234-7770 Fax: (808) 234-7775 Email: aecos@aecos.com

Executive Summary

A sewage main completed in 1977 moved treated sewage from a discharge point in South Kāneʻohe Bay to a deep outfall off Mōkapu Peninsula. The environmental benefits to the Bay were soon apparent, and recovery of the coral reefs has continued over the last 30 years. A pipeline to replace or supplement this 1977 pipe connecting the Kāneʻohe Wastewater Treatment Plant to the ʻAikahi plant is now proposed. One alternative is to use slant drilling from behind the Kāneʻohe and ʻAikahi shores to deploy the pipe under the sea floor to avoid disturbance to the marine biota. Original alternatives for this deployment included possible connection points within the Bay where box-shaped areas would have been isolated by sheet pilings driven into the bottom sediment and material removed dredged to allow access to connect pipe ends. However, the final plans are: in-water construction activities are not contemplated for pipeline deployment. The present study was conducted to evaluate areas along the subterranean pipeline that would be sensitive to construction-related activities were these required for the pipeline deployment.

Surveys were conducted September through November 2009 to define the benthic and fish communities in the project area. Initial rapid visual assessments of the biota were conducted at stations located 500 ft apart along two alternative pipeline routes. These visual assessments were followed by quantitative measurements (percent cover) of benthic organisms at each station using two, 10-m long transects. At deeper lagoon sites, found to be entirely fine sediment bottom, transects were not used, but counts were made of the number of burrow openings as an indication of the presence of organisms living within the sediment. Sediment meiofauna (very small infaunal organisms) were sampled within the fine lagoon sediments as well off the mouth of Kāneʻohe Stream and from coarser sediments on the reef flats.

Survey results show that most of the reef flat environment along the proposed pipeline routes is highly degraded and dominated by invasive algae, with reef corals absent and reef fishes present in low abundance. Macrobenthos and fish are virtually absent on the reef flat off Kāneʻohe Stream. The only substantial coral reef cover and reef fish populations occur on a series of linear bottom features in a previously dredged area, 6000 to 7000 ft from the Kāneʻohe origin of the Blue Line, at a point where the proposed pipeline would bend toward the ʻAikahi shore. A substantial growth of seagrass also occurs in this area. An area with intermediate coral cover and reef fish abundance is found near the reef edge at 2000 ft from the Green Line origin. Smaller amounts of coral cover occur on reef slopes near the 7000 and 8000-ft Blue Line stations. These areas are the only ones potentially sensitive to disturbance arising from pipeline deployment. No endangered or threatened marine species would have been impacted by pipeline deployment, and a species of concern formerly abundant in south Kāneʻohe Bay, the articulated brachiopod, *Lingula reevi*, has been found to be virtually absent in recent years.

Because pipeline deployment is proposed through subterranean slant drilling, the only unavoidable impact to marine communities would have been at connection point shafts where pipe ends would have been joined. Seven possible locations were evaluated using sediment infaunal densities for macrofauna and samples of meiofauna taken at three of these. Although the estimates indicate that millions of individuals (and up to 100 kg of macrofauna) would have been removed from the upper layer of sediment by dredging out a 200 x 200-ft connection shaft, these impacts would be temporary, and the sediment infaunal community would recover once construction was completed and bottom sediments restored to the dredged area(s). A bigger concern was isolating dredging turbidity plumes from adjacent sensitive areas. Recommendations are made herein for locating any emergency in-water activities related to pipeline construction as far as feasible from sensitive coral bottom and seagrass areas.

Introduction

Project Description

A subterranean pipeline placed beneath Kāneʻohe Bay has been proposed as an alternative to a land-based route for a new pipeline (sewage force main) to supplement or replace the existing pipeline linking the Kāneʻohe and Kailua (ʻAikahi) Wastewater Treatment Plants (WWTP) on windward Oʻahu,

Two alternative routes crossing the south part of Kāneʻohe Bay (Fig. 1) were considered:

- A route from the Kāneʻohe WWTP, beginning near the east bank of Kāneʻohe Stream extending northeast to the Kailua WWTP, herein referred to as the "Blue Line" route.
- A route beginning at the shoreline in the vicinity of the Kokokahi YWCA and extending north-northeast to intersect the Blue Line route to the Kailua WWTP, herein referred to as the "Green Line" route.

Both alternatives follow along the same route on the Kailua (ʻAikahi) half of the proposed project using slant drilling from the Kāneʻohe and ʻAikahi shore areas. Original alternatives for this deployment included possible connection points within the Bay where box-shaped areas would have been isolated by sheet pilings driven into the bottom sediment and sediments dredged out to expose pipe ends for joining. However, no in-water construction activities are now in the final plan for the pipeline deployment.

Marine biological surveys were conducted in September through November 2009 by *AECOS*, Inc. biologists along the alternative routes of the subterranean pipeline. This report details findings from these surveys.

Figure 1. Southern Kāneʻohe Bay showing alternative "blue" and "green" pipeline routes as a series of stations set 500 ft apart. Note that the green route would continue northeast to ʻAikahi as the blue route beyond 5000 ft.

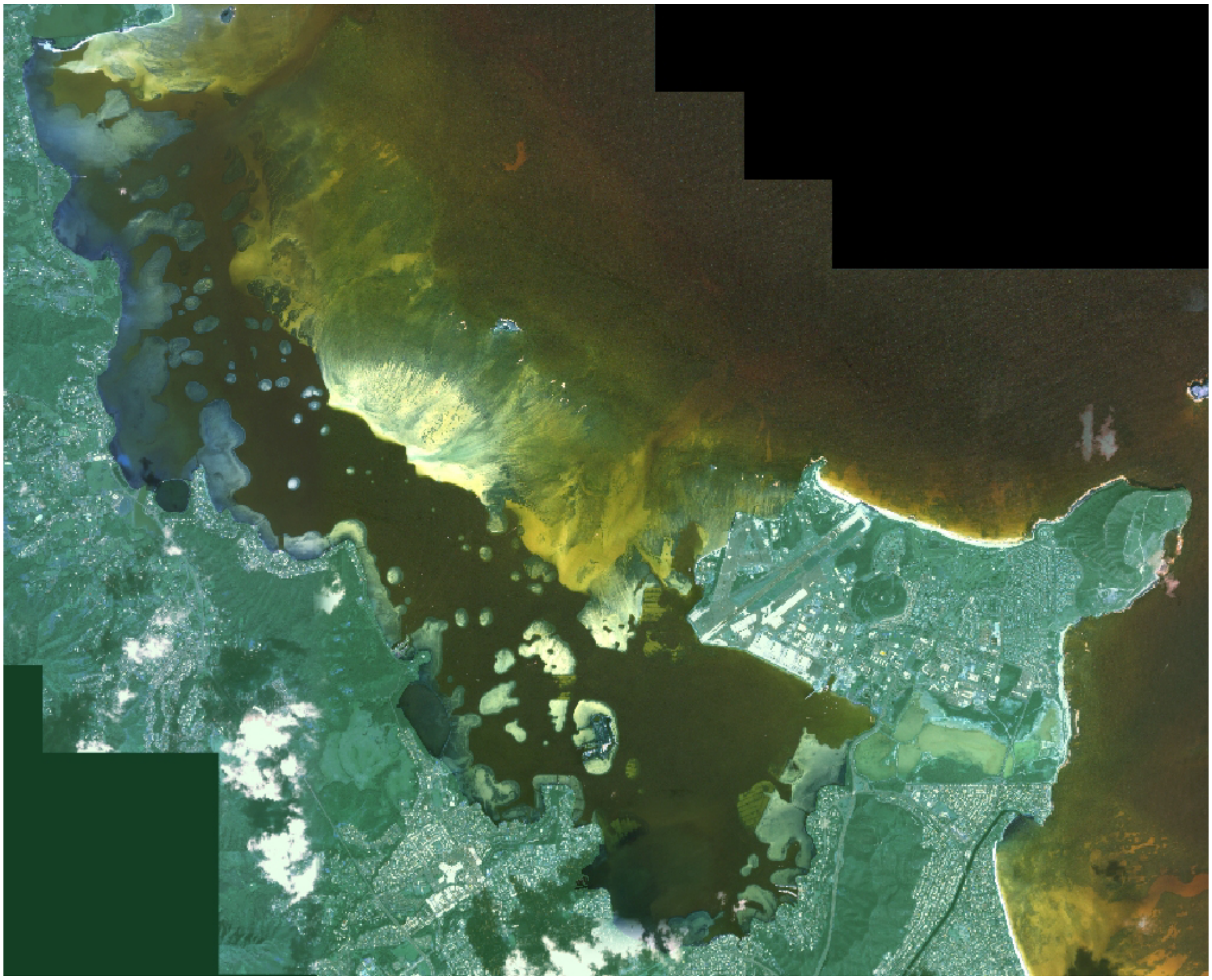

Figure 2. Aerial view of Kāneʻohe Bay.

Environmental Setting

Kāneʻohe Bay is the most prominent nearshore marine feature on the windward side of the island of Oʻahu, Hawaiʻi and is the largest sheltered embayment in the Hawaiian Islands, with the only well developed barrier reef system in the Islands (Fig. 2). It is approximately 13-km by 4-km wide oriented in a northwest–southeast direction and receives the drainage of a watershed of approximately 97 km^2 from a number of streams that flow down from a boundary of near-vertical cliffs that enclose the watershed. The bay's seaward side is semi-enclosed by a barrier reef that extends across its mouth, with channels at the northwest and southeast ends of the barrier reef that allow increased access of open ocean water into the bay. The interior of the bay is a lagoon surrounded by fringing coral reefs and numerous patch reefs that become more numerous going northward in the bay. Salinities in the bay range from near oceanic levels (35 PSU[1]) in open water areas, but can drop to less than half that value in shallow depths following torrential rainstorms. Water temperatures can range between 13 and 33°C but average about 18 to 29°C annually. Bottom depths in the bay range from awash on flats during lowest tides to 10+ m (33+ ft) in the lagoon. Sediments on the lagoon floor are flocculent silts and clays with a substantial terrigenous component and on reef flats, sediments are fine to medium grain calcareous sands, with sand becoming a greater proportion of the sediment going northward in the bay.

Based upon degree of isolation from the open ocean, circulation patterns, and environmental attributes, the bay is usually differentiated into three major areas. The north bay section extends from the north entrance channel about one third of the distance southward to Kahaluʻu Point and is the most pristine part of the bay with the most patch reefs, highest coral cover, and lowest nutrient and particulate organic concentrations in the water. Next southward is the central bay, extending to a line between Mōkapu Peninsula and Coconut Island and intermediate in its characteristics of circulation, reef development and nutrient/particulate concentrations. The south bay is enclosed by land on three sides and consequently has the least exchange with open ocean circulation, the highest turbidity and nutrient levels, and most limited reef development in comparison with the other two sections. Water circulation in this sector is generally clockwise, entering from the north between Coconut Island and Mōkapu Peninsula, flowing through the south bay and reentering the central bay west of Coconut Island. Residence time is approximately two weeks. The lands surrounding the south bay are more developed (urban and suburban) than the watersheds draining to the north and central sectors. Fresh water runoff and flooding are therefore more significant factors here than elsewhere in the bay, and dense turbidity plumes are often visible over substantial areas of the south bay following intense rainstorms in Kāneʻohe. An extensive annotated bibliography of information related to the environment, ecology, and history of Kāneʻohe Bay is included as Appendix A.

Historical Perspective

Kāneʻohe Bay has long been recognized as a unique marine environment that once supported abundant reef corals and associated marine life. The earliest report (Wilson, 1922) was from James Macrae, botanist on Byron's voyage to Hawaiʻi in 1824-1826 who noted that Kāneʻohe Bay was open, exposed and "full of rocks in many places above water which renders it unsafe for vessels to

[1] PSU = practical salinity unit; replaces the older parts per thousand (ppt) for technical reasons.

anchor. It is full of fish." Agazzis (1889) described Kāneʻohe Bay to have its bottom "covered in many places by numerous more or less circular patches of living corals in all stages of growth… with their sides covered with magnificent clusters of *Pocillopores* and *Porites*… and the simpler *Fungiae* so characteristic of the Pacific reefs." MacKaye (1915) mentioned "over a hundred varieties of corals are known to exist in Kāneʻohe Bay" that were colored "yellow, red, green, brown, and lavender, with snow-white corals making bright spots along the reefs". He listed the 16 major coral species that composed the "coral gardens" in the south bay, which was in the vicinity of the present Makani Kai Marina. MacCauhghey (1918) remarked that in Kāneʻohe Bay there were"many small coral isles and atolls; some are of notable perfection and that in the bay "in protected waters of inner channels or lagoons that corals attain their finest development". (Edmondson, 1928) described the bay as "one of the most favorable localities for the development of shallow water corals" with "nearly all the reef-forming genera known in the Hawaiian Islands … represented in certain areas of this bay and many species grow luxuriantly."

The Kāneʻohe Bay region was a major Hawaiʻi population center prior to and for a time after European contact. The bay area included nine *ahupua'a* valleys extending from the mountaintop to the sea and about 30 fishponds and was highly productive. Population at the time for Kāneʻohe at European contact has been estimated variously as around 15,000 to 17,000 (Devaney, et al., 1976). Following European contact the native population of the Kāneʻohe Bay region fell precipitously due to introduction of diseases, disruption of native society, and culture and emigration into the growing district of Honolulu across the Koʻolau. By the time of the first Hawaiʻi census in 1831, the population of the nine Kāneʻohe *ahupua'a* was recorded as 3,019. Population for the district reached its lowest in 1872, when only 2,028 persons were recorded, or about 4% of the 1831 value and only about 10% of the number estimated some 100 years earlier. Although population began to increase in the 1870s, the 1831 value was not reached until the 1920s. Population for Koʻolaupoko District then doubled in less than 20 years, reaching 9000 in 1940, and then again in ten years with over 20,000 in 1950, the population distributed about evenly between Kāneʻohe and Kailua-Waimanalo areas.

Considerable change occurred in the water quality and marine environment in Kāneʻohe Bay with urbanization and development of the watershed in the second half of the 20th century. This phase of the history of windward Oʻahu and Kāneʻohe Bay began in about 1945 as residents of Honolulu began to utilize the improved Pali Road to visit the area, with many people eventually making their homes in Kāneʻohe-Kailua once the modern Pali (in 1957) and Likelike (in 1960) highways were completed. The enhanced accessibility to Honolulu urban centers that these roads afforded, resulted in the Koʻolaupoko District population increasing rapidly, reaching 92,000 in 1970, 110,00 in 1980 and 122,000 in 1995. Most of the population increase in the last 30 years has occurred in the Kāneʻohe area, which accounted for 60,000 of the 110,000 for the Koʻolaupoko district in 1980 (Smith, et al., 1980). This "opening up" of the windward side resulted in considerable impacts to Kāneʻohe Bay. The hardened surfaces of roads, parking lots and roofs diverted rain water into storm drains and streams that previously would have percolated into the ground, but now flowed quickly into the bay, along with sediments from hillside slopes uncovered by construction and development. Nine of the bay's 30 fishponds that are indicated to have existed in the 19th century were filled between 1946 and 1948 and used for housing sites, and only 12 of the original ponds remain today. Principally as a result of extension and development of the Kāneʻohe Marine Corps Base just prior to World War II, large areas of the Bay were dredged and filled, especially in the south bay in the vicinity of Mōkapu Peninsula. Between 1939 and 1941 over two million cubic yards of reef area were dredged in areas on the bay side of Mōkapu and much of the material used to extend the shoreline for the Marine Base runways (Devaney, et al., 1976).

The Marine Base was also the first source to release sewage into the bay, beginning with the discharge of untreated primary sewage in the southeast bay in the 1940s. In 1971 sewage treatment at the Marine Base was upgraded to secondary (removal of suspended solids and reduction of organic load). Prior to 1963 municipal waste from Kāneʻohe town was handled by a network of cesspools and septic tanks. In 1963, the Kāneʻohe WWTP became operational, utilizing secondary treatment and discharging effluent into south Kāneʻohe Bay at a depth of 8 m. In 1970 a small secondary treatment constructed for a housing development at ʻĀhuimanu began discharging in central Kāneʻohe Bay. By 1975 the total sewage discharge from these three sources had risen to a total of about 17,000 m^3/day, with about 70% of the total coming from the Kāneʻohe municipal discharge into south Kāneʻohe Bay.

By the early 1970s the water quality and marine environment of Kāneʻohe Bay had been severely degraded, especially in the south basin where a residence time for water of approximately two weeks (Bathen, 1968) meant that nutrients and suspended solids discharged by the sewage outfalls, streams and shoreline runoff accumulated, stimulating phytoplankton growth. Conditions at that time in the bay were described in several publications (Banner and Bailey, 1970; Maragos, 1972, 1973; Smith, et al., 1973; Banner, 1974; see also Laws, 1981 for a summary discussion). It had been evident for years that effluents were causing eutrophication and biological damage in the bay, especially in the south basin where reef corals had essentially ceased to occur (Maragos, 1972; Laws and Redalje, 1979). A benthic community dominated by suspension and deposit feeders such as sponges, zoanthids, polychaetes and tunicates utilizing the increased organic load and plankton productivity replaced the former coral bottom community. Distributions of corals (Maragos, 1972, 1973) as well as macroalgae (Soegiarto, 1973), and reef fishes (Key, 1973) showed dramatic decreases in the south basin, and corals transplanted into this area failed to grow or survive (Maragos, 1972). Mid-bay shallow reefs were dominated by an invasive macroalga, *Dictyosphaeria cavernosa*, which overgrew corals and weakened their skeletons (Banner and Bailey, 1970; Maragos, 1972). A study of the bay's bathymetry (Roy, 1970) comparing depths from 1882 and 1927 charts with fathometer readings made in 1969, indicated no significant change between the two earlier dates, but showed a mean decrease of 1.6 m to have occurred between 1927 and 1969. The composition of 72% of the sediment deposited was carbonate, suggesting that reef degradation and subsequent erosion exceeded reef growth during this period.

In order to counter the impacts of sewage-induced eutrophication, construction began in 1975 to transfer Kāneʻohe sewage to a deep ocean outfall at about 30-m depth off Mōkapu Peninsula outside Kailua Bay. All sewage discharge was permanently diverted from Kāneʻohe Bay to the deep outfall in May 1978. The reduced nutrient loading in the bay quickly manifested itself in reduced plankton, suspended solids, and turbidity in the south bay. The benthic community shifted from dominance by suspension and deposit feeding detritovores to autotrophic algae and reef corals which could utilize the improved light penetration of the water column (Smith, 1981). Resurveys of reef sites in the bay in 1983 (Maragos, et al. 1985; Alino, 1986; Evans, et al. 1986; Holthus, et al. 1986; Holthus, et al., 1989; Guinther and Bartlett, 1986) revealed a shift in the composition of reef organisms and a remarkable recovery of corals, especially *Porites compressa* and *Montipora verrucosa* (= *M. capitata*) in the south and middle sectors, while *Dictyosphaeria cavernosa* declined greatly except for a minor increase in the northern sector.

Along with the impact of sewage discharge, an important environmental factor affecting Kāneʻohe Bay has been periodic runoff from torrential rainstorms. Major storms occurring in 1965 (Banner, 1968) and 1987 (Jokiel, et al., 1993) had somewhat contrasting impacts on the benthic communities over the long term. Both storms yielded sediment laden, low salinity water over the shallow depths of the reefs that resulted in extensive mortality for benthic organisms and fishes. Damage from the 1965 storm was long-term on some shallow reefs directly impacted by the flood in the south bay, which underwent a shift in the dominant benthic component from reef corals to the colonial anemone, *Zoanthus* (Banner, 1968; Maragos and Chave, 1973). After removal of sewage discharge from the south bay, the *Zoanthus* population diminished, probably due to food limitation, and the 1987 storm did not produce another shift to

Zoanthus dominance, but rather a recovery of corals from tissues remaining in the apparently dead coral skeletons (Jokiel, et al., 1993).

Measurement of nutrients and other water quality indicators during the early 1990s indicated that nutrients had remained near or below the lowered values that had been measured during monitoring following the removal of sewage discharge from the bay in 1978 (Coles and Ruddy, 1995; Laws, et al., 1996). Corals transplanted to four sites where Maragos (1972) had previously shown high mortality in the south bay during the period of sewage discharge showed good survival and growth in 1991-92 (Coles and Ruddy, 1995). However, surveys conducted on benthic coverage throughout the bay suggested that the rate of coral recovery established in 1970 and 1983 had slowed or, in some cases, reversed and *Dictyosphaeria cavernosa* was again increasing at a third of the sites surveyed (Evans, 1991; Evans and Hunter, 1992; Hunter and Evans, 1995). Studies of the nutrient dynamics of *D. cavernosa* (Larned and Stimson, 1996; Stimson, et al., 1996; Larned, 1998) suggest that sediments function as localized nutrient sources, making sustained algal growth possible despite low nutrient concentrations in the water column, and that nutrient regeneration from sediments beneath thalli, and/or excretion by animals inhabiting these chambers contribute to the elevated nutrient levels utilized by the algae.

The other prominent change in Kāneʻohe Bay in the last two decades has been a growing dominance of the benthos by nonindigenous (introduced) species. In a comprehensive survey at 24 locations in the bay in 1999-2000, Coles et al., (2002) found a total of 116 introduced or cryptogenic species, mostly invertebrates, comprising 23% of the total taxa identified in the study. Invasive (alien) algae are of particular concern (Rodgers, 1997; Rodgers and Cox, 1999; Coles et al., 2002, Smith and Hunter, 2002). The first introduced algae noted in Kāneʻohe Bay was *Acanthophora spicifera,* which was reported by (Doty, 1961) who mentioned Kohn (1959) recording this species on the egg cases of *Conus quercinus* collected in Kāneʻohe Bay This alga is believed to have been accidentally introduced into Pearl Harbor on a barge during WW II (Doty, 1961; Russell, 1992). The remaining algal introductions were purposeful as potential aquaculture species that did not prove practical or profitable but managed to proliferate on their own. The most thoroughly documented introductions were various species of *Kappaphycus* or *Eucheuma* (Russell, 1983) which were introduced by Doty in 1974 and rapidly spread over the reef on which they had been placed. Although originally proposed to be limited in ability to disperse because of light limitations that prevent survival in deep water (Russell, 1983), subsequent surveys (Rodgers and Cox, 1999) have shown *Kappaphycus* to had spread throughout the bay at an average rate of 250 m per year, or over 6 km from its point of introduction in 1974. Another algae introduced in that year, *Hypnea musciformis* from Florida, was originally planted on reefs in Kāneʻohe

Bay and while not prominent in the bay, has spread to many other locations on Oʻahu and other Hawaiian islands, becoming an especially invasive pest on the south and west coasts of Maui. The most recent introduction, *Gracilaria salicornia,* has proliferated rapidly since its introduction in 1978, with an average rate of spread of approximately 280 m per year in the bay (Rodgers and Cox, 1999). This is now the most widespread and abundant alien algae in the bay, where it covers large areas of shallow reef, especially in the south bay.
Both *Kappaphycus* and *G. salicornia* smother and displace live coral and native species of algae on reefs and prevent the utilization habitat by reef-associated invertebrates and fishes. Additional competition with corals by an invasive sponge, *Mycale grandis*, has been recently reported (Coles and Bolick, 2007) that may limit further reestablishment of corals on the reefs in the south bay.

During the last two decades increasing popularity of Kāneʻohe Bay and perception of its value as a recreational and income-producing asset has resulted in competition among user groups for the bay's space and resources. The bay is now heavily used by recreational and commercial fishermen, power and sailing boaters, tourist-oriented business providing experiences in snorkeling, high speed watercraft, glass bottom boat tours, and scientific research at the Hawai`i Institute of Marine Biology (HIMB), from which scientists have studied the bay for over 50 years. The mix of these activities sometimes conflict and optimizing usage among them has been the objective of the Kāneʻohe Bay Task Force.

The history of Kāneʻohe Bay illustrates a resource that has always been considered of high value, but has always been highly affected by activities on its watershed and shoreline, as well as those occurring directly within the bay waters Over the last century the bay has gone from near pristine condition to a highly degraded state, then through a degree of recovery following cessation of sewage discharge, and finally to the present state with some reestablishment of reef corals and associated organisms, but also symptoms of decline and interference from introduced species.

Methods

Rapid Visual Assessment Surveys

Marine biological surveys were conducted on September 11 and 14 by three *AECOS* marine biologists along the proposed alternative routes of the subterranean pipeline to link the Kāneʻohe and Kailua (ʻAikahi) WWTPs. Both the proposed Blue Line and Green Line routes were addressed, with survey stations established every 500 ft along the two routes. Latitude-longitude coordinates of these stations were loaded into a Garmin Etrex Summit GPS receiver for locating in the field. The Blue Line had 20 marine stations out of 23 stations, and the Green Line had 9 marine stations out if 11 stations for this route (Fig. 1, above).

All marine stations were surveyed by three biologists, each noting depths, substratum characteristics, and the species and relative abundance of algae, invertebrates, and fishes that could be identified in the field. Vouchers of some specimens were collected and returned to the laboratory for subsequent identification. Most stations were surveyed by snorkeling. Scuba was used in making observations from Stas. 5500 to 7000 along the Blue Line route where live corals and associated organisms occurred. Except at points in the lagoon at depths greater than 12 ft (4 m), investigators swam between all designated sites and made observations to verify that station biological and substratum observations were typical of the surrounding area.

Quantitative Transect Surveys

Determinations of benthic coverage along transects laid on the bottom were made at all stations along the Green and Blue Lines except for those stations characterized entirely by soft sediment (Stas. 1000 to 5500 Blue Line and Stas. 2500 to 5000 Green Line). Locations of the transect start and end points are plotted in Fig. 3.

Transect surveys were conducted October 16 through 29, 2009. A 25-m transect line was deployed at the station and surveyed in two segments, each 10 m long[2]. The start and end of each transect were recorded using a Garmin E

[2] The practice of using a single 25-m line divided into two 10-m transects appears to be widely used in Hawaiʻi in marine surveys, and typically the data are presented as two transects from a site. Although the advantages of laying out transects in this manner seems minimal, the disadvantage that the results cannot be analyzed as two, independent transects per site easily outweighs the ease of a single setup of a survey line.

trex Summit GPS. Macro-organisms with low abundance along a transect were entered into field notes as "present." Quantitative quadrats utilized one of three methods, depending on water depth at a station.

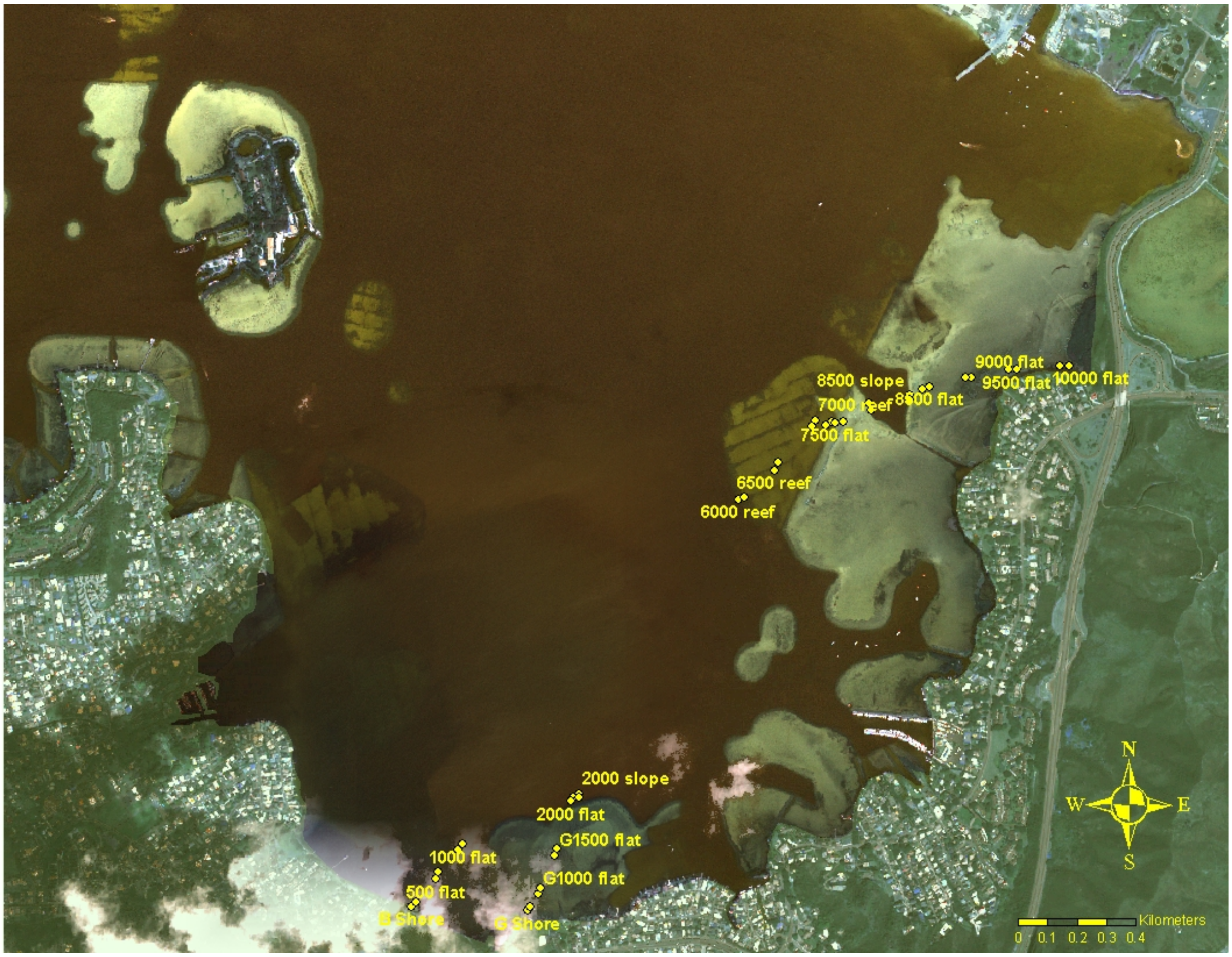

Figure 3. Locations of surveys conducted near Blue and Green pipeline sites, October 16-29, 2009.

1. Photoquadat-0.66 m^2/quadrat. In depths of water around 3 m (10 ft), a digital camera in an underwater housing was supported on a frame 1.2 m above the bottom, giving an image covering 1.0 x 0.66 m. Photos were taken every meter along the two 10-m segments of the transect. The quadrat photographs were analyzed on a computer using Coral Point Count with Excel extension (CPCe) software (Kohler and Gill, 2006). Quadrat photos were cropped to a consistent area of

0.67 m^2 and enhanced to an optimal image as needed. The organisms or substratum type under 50 points randomly generated for each image were recorded for a total of 1000 points per transect. These data were used to determine the percent cover of macroalgae, corals, other invertebrates sufficiently abundant in the quadrats to be detected by the method, and substratum type, which were averaged for each transect at each site. This method and analysis was used for Stas. 6000, 6500, and 7000 and on the reef slope at Stas. 7000 and 7500 along the Blue Line (Fig. 1).

2. <u>Photoquadat-0.165 m^2/quadrat</u>. For sites up to 0.5 m depth, or where water turbidity was so high that a larger focal distance could not be used, a smaller support frame with a quadrat area 0.5 x 0.33 m was used putting the camera housing at 0.5 m above the bottom. The same techniques as described above for Method 1 were used, except that images were separated by 0.5 m along the two 10 m segments. This method was used for transects on the reef flat at Stas. 1500 and 2000 and on the reef slope at Sta. 2000 along the Green Line; and at Stas. 7000 and 8000 (reef flat and reef slope) on the Blue Line.

3. <u>Quadrat Frame-0.25 m^2/quadrat.</u> For stations in less than 0.5 m depth, a 0.5 x 0.5 m square frame subdivided by thin nylon lines at 10-cm intervals to form a grid of 25 intersecting points was used. Laid on the bottom, the organism or substratum type lying under each of the intersections was recorded. As in Method 2, measurements were made every other 0.5 m along each 10 m transect segment, and values for each entity were totaled and averaged for each of the two segments. This method was used for reef flat stations near the shoreline and at Sta. 1000 on the Green Line; and near the shore and at Stas. 8500, 9000, 9500, and 10000 along the Blue line.

Sediment Macrofauna

Seven locations shown in Fig. 4 were surveyed November 2009 for the presence of epibenthic animals[3]. At each location, observers swam cardinal directions from the center of the box, located by GPS, inspected the bottom for indications of macrofauna, (i.e. organisms large enough to be visible on the bottom), and recorded the number of burrow openings on the sediment surface within a 0.25 m^2 quadrat haphazardly placed on the bottom. The sediment itself was sampled for infauna at three of the seven sites by divers inserting a 28-cm diameter

[3] Epibenthic means living on the bottom; infauna refers to living within the benthic (bottom) substratum.

cylinder, 35 cm into the soft bottom and capping the cylinder from below, then later sieving the contents through quarter-inch (6 mm) mesh screen.

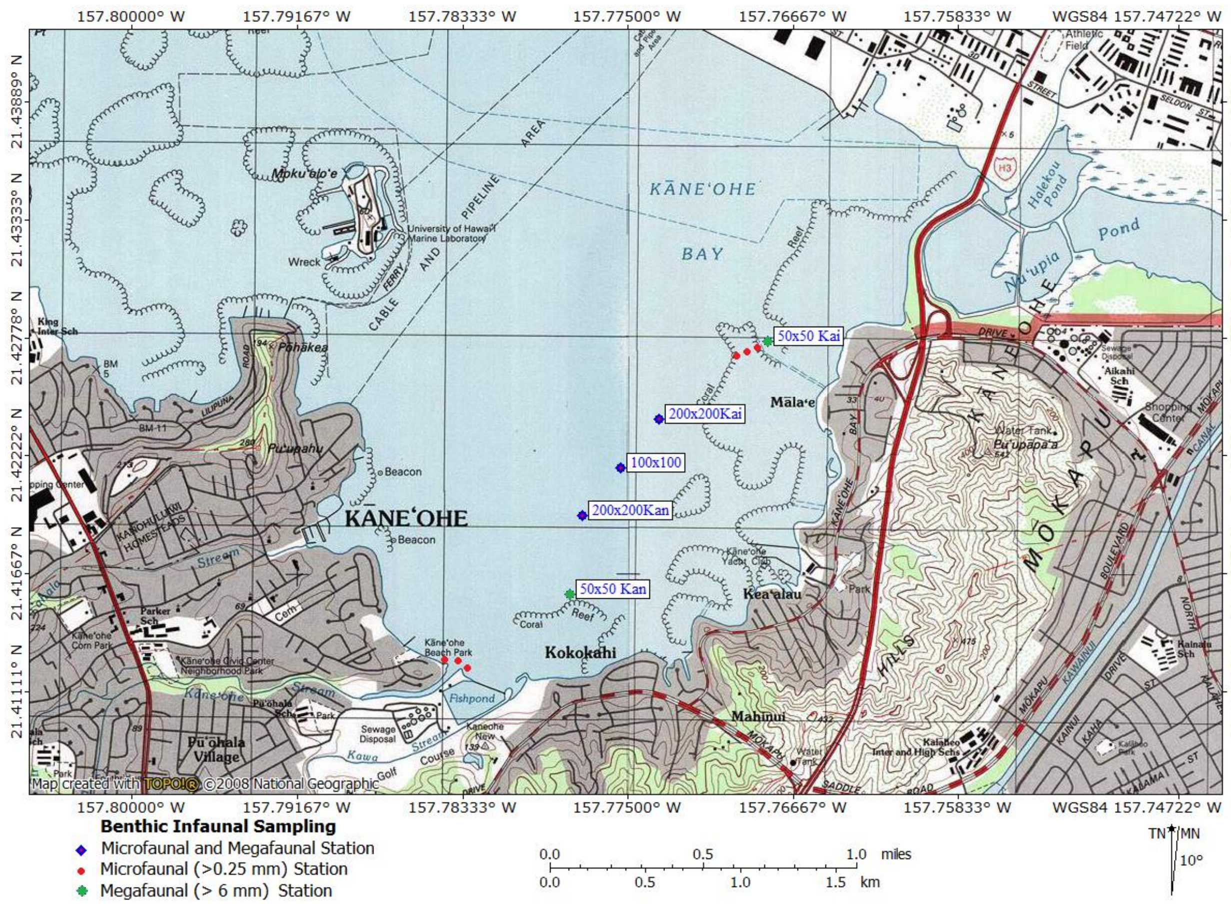

Figure 4. Locations of sediment infauna observations and sampling.

Sediment Meiofauna[4]

To sample the meiofauna living in the sediment in various locations, glass screw-cap jars of 450 ml capacity were used to core vertically down into the upper 5 to 10 cm of sediment. Samples were hand collected by divers from within the reef flat mud/sand mixture adjacent to Kāneʻohe Stream (0-0.5 m

[4] Benthic infauna live within the sand or mud in this case; the majority of these sediment-dwelling organisms are part of the meiofauna, organisms so small they easily pass through a 1 mm screen sieve.

depth), from the reef flat at Sta. 7500 on the Blue Line (1-3 m depth), and from the deeper lagoon floor (10-13 m depth) sediment at the three potential connection sites. Sampling locations are shown in Fig. 4. Three replicate samples were collected from each location. The overlaying water was then strained through a 0.25 mm sieve and any organisms retained on the sieve were backwashed with formalin into the sample.

Two sieves (0.5 mm and 0.25 mm mesh) were used to trap individual specimens in the sediment samples. Specimens were transferred to 70% ethanol, sorted to major taxa, and stored in glass vials in 70% ethanol. Taxa were identified using dissecting and compound microscopes and regional keys. This method successfully separated all organisms from the sediment that were not heavily calcified. Polychaetes and other invertebrates retained on the sieve were stained with rose bengal. All specimens were identified to the lowest taxonomic level possible at the Wormlab at the University of Hawaiʻi.

Reef Fishes

On October 15, 23, and 26, 2009, *AECOS* biologists conducted belt transect fish surveys of three shallow water environments in south Kāneʻohe Bay to characterize the fish assemblages in the general project area. The fish observations were conducted on sand flats, reef margins and slopers, and deeper coral bottom environments, utilizing the same transects as described for the quantitative benthic surveys (Fig. 3). Each 25-m transect was surveyed by a diver swimming the length of the line and identifying and estimating total body length of all fishes present within 0.5 to 1 m (1.5 to 3 ft) of either side of the line, depending on visibility. Live wet weight (W) of fishes recorded was calculated from the visually-estimated total length (TL) using the relation $W = a(TL)^b$ (Friedlander and Brown, 2006). That is, biomass equals total body length measurement multiplied by known length conversion factors a and b (provided by Hawaiʻi Cooperative Fishery Research Unit, University of Hawaiʻi, unpublished data). The derived biomass values for each transect are then summed and converted to kilograms per hectare. This underwater visual survey technique (Brock, 1954; Brock, 1982), which is standard for surveys of this kind, does not accurately census seasonal, cryptic, nocturnal, and burrow-inhabiting fishes, although they may comprise half or more of the extant fish assemblage in a reef environment (Willis, 2001). These latter groups can be extremely difficult to account for in a onetime visual censusing.

Results

Qualitative Benthic Survey Observations

The general characteristics and dominant organisms found at the sample stations and in some areas between stations are shown in Table 1 for the Blue Line route and in Table 2 for the Green Line route. Most of the sites occurred at locations where the substratum was fine sediment at depths ranging from 12 to 42 ft (4 to 13 m), with burrow openings the only indication of the presence of macrofauna. Such was the case at ten sites along the Blue Line from Stas. 1000 to 5500, and six sites along the Green Line from Stas. 2500 to 5000.

The second most frequent environment encountered was that of shallow sand flats dominated by introduced marine algae with depths of 3 ft (1 m) or less. This occurred at 7 Blue Line stations, from the shore to a point between Stas. 500 and 1000, from Sta. 7500 to the shore near ʻAikahi, and at three of the Green Line stations, from the shore near Kokokahi to Sta. 2000. Although there is some variability among dominant and secondary species, most of these areas were heavily covered with invasive red algae, *Acanthophora spicifera* and *Gracilaria salicornia*, the latter very abundant between the ʻAikahi shore and Sta. 10000. Other abundant species were the blue-green alga, *Lyngbya majuscula*, and the green alga, *Dictyosphaeria cavernosa*; the latter once dominated shallow areas in south Kāneʻohe Bay, but has become less common in recent years.

No reef corals or associated organisms were found on reef flat locations except at the reef margins adjacent to deeper water. Coral patch reefs occurred between Stas. 5500 and 6000 and at Sta. 7000 on the Blue Line, and about 50 ft outside of Sta. 2000 on the Green Line. The Blue Line coral areas from Stas. 6000 to 7000 are a series of linear bottom features with high cover of *Montipora capitata* and *Porites compressa*, and abundant *Mycale grandis* (a sponge) and *Sabellastarte spectabilis* (feather duster worm) living among the corals. These features occurred at depths from 8 to 10 ft (2.5 to 3 m) and are separated from the reef flat by a sand channel. A large bed of the Hawaiian endemic seagrass, *Halophila hawaiiensis*, occurred between Stas. 7000 and 7500 on the Blue Line and coral coverage was minimal at the reef margin where bottom cover was dominated by *Gracilaria salicornia*. The Green Line reef area outside Sta. 2000 had a moderate cover of *Montipora capitata, Porites compressa*, abundant *Sabellastarte spectabilis*, and moderate cover of *Gracilaria salicornia.*

Marine organisms recorded along the Blue and Green routes are listed in Table 3. A total of 72 taxa were found: 18 macroalgae, 2 flowering plants, 34 invertebrates, and 18 fishes. Of these, 15 of the species are introduced or cryptogenic[5], or 21% of the total, and 57 are native species, including two species that are considered endemics (i.e. occurring only in the Hawaiian Islands): the sea-grass, *Halophila hawaiiensis*, and the coral, *Porites compressa*.

Table 1. Characteristics and dominant biota along Blue Line route

Station	depth (ft)	Description
Shore	2	Sand & silt, abundant rubbish, with scattered algae.
Btw		Cobbles in sand/silt, with shell fragments, burrow openings; *Acanthophora spicifera* & *Gracilaria salicornia* abundant.
500	3	Level black sand/silt with sparse scattering of mixed algal mats (most <15 cm to 25 cm diam.).
Btw		Level, black sand/silt; algae, sea-grass, & sponges rare.
1000	12	Silt bottom; numerous burrow opening.s
1500	17	Silt bottom; numerous burrow openings.
2000	26	Silt bottom; numerous burrow openings.
2500	32	Silt bottom; numerous burrow openings.
3000	35	Silt bottom; numerous burrow openings.
3500	36	Silt bottom; numerous burrow openings.
4000	37	Silt bottom; numerous burrow openings.
4500	35	Silt bottom; numerous burrow openings.
5000	39	Silt bottom; numerous burrow openings
5500	42	Silt bottom; numerous burrow openings.
Btw		Reef margin adjacent to Sta. 5500, with high cover of *Porites compressa, Montipora capitata* & abundant *Sabellastarte spectabilis.*
6000	8	Coral cover 75-85%. *Porites compressa* dominant with abundant *Montipora capitata, Dictyosphaeria cavernosa* & *Mycale grandis.*

[5] A "cryptogenic" species is one whose origins are uncertain; that is, a species that may be native or may be introduced (alien).

Table 1 (continued).

Station	depth (ft)	Description
6000		
Btw		Linear coral patches in coarse coral sand, some *Lyngbya majuscula* mats.
6500	10	Isolated reef 6 ft deep with M*ontipora capitata* dominant, *Porites compressa, Sabellastate spectabilis,* & *Mycale grandis* abundant.
Btw		Coral sand with *Lyngbya majuscula* patches, small *Montipora capitata* reefs and sea-grass bed.
7000	9	Linear coral growth feature in medium grain sand ca. 50 ft from reef edge. Abundant M*ontipora capitata, Porites compressa, Sabellastate spectabilis,* & *Mycale grandis.*
Btw		Coarse sand to reef edge where only coral is scarce *Montipora capitata*, some heads bleached; abundant *Gracilaria salicornia*, and a large seagrass bed.
7500	2	Sand flat dominated by *Acanthophora spicifera, Gracilaria salicornia,*& seagrass; corals rare.
Btw		Rubble at reef edge, abundant burrow openings, 10% cover of *Gracilaria salicornia* on reef sand flat, with abundant *Lyngbya majuscula,* turf tubeworms, sparse *Mycale grandis* & sea-grass on reef flat
8000	28	Pipe *i*n coral sand ca. 100 ft from reef with *Acanthophora spicifera* & sparse *Halichondria caerulea.*
Btw		Reef edge ca. 100 ft from #18. Very little *Montipora capitata* with ca. 80% cover *Gracilaria salicornia and Lyngbya majuscula* mats on medium grained sand.
8500	2	Reef flat with medium grained sand and sparse seagrass, large clumps of *Acanthophora spicifera, Gracilaria salicornia & Lyngbya majuscula*, with small amount of *Dictyosphaeria cavernosa*
Btw		Sand flat with abundant large clumps of *Lyngbya majuscula*, less *Acanthophiora spicifera, Gracilaria salicornia, & Symploca hydnoides* with occasional *Opheodesoma spectabilis*
9000	1.5	20% *Gracilaria salicornia* in fine sand & rubble, w/ some *Symploca hydnoides* & *Lyngbya majuscula*
Btw		Same as 9000 with *Gracilaria salicornia* decreasing to 10% in fine sand with some *Acanthophora spicifera*
9500	1	<10% *Gracilaria salicornia* in fine sand, & coral rubble, mangrove starting
Btw		Same as 9500; *Gracilaria salicornia* increasing in abundance.
10000	1	50 ft from shore, thick 90% cover G*racilaria salicornia*, many mangrove shoots.
Btw		Mangroves off the shore.
10500		Land

Btw = On Blue route between the stations before (above) and after (below).

Table 2. Characteristics and dominant biota along Green Line route

Station	depth (ft)	Description
0		Land
500		Land
Btw		*Acanthophora spicifera* & *Gracilaria salicornia* in small patches among sand and pebbles, 50 ft from shore; algal cover increases going seaward.
1000	3	Abundant mixed *Acanthophora spicifera, Gracilaria salicornia,* & *Lyngbya majuscula* in medium grain sand; numerous burrows of alpheid shrimp with commensal and gobies.
Btw	3	Abundant *Lyngbya majuscula* & *Acanthophora spicifera*, some *Caulerpa sertularioides* & *Dictyosphaeria cavernosa* in medium grain sand.
1500	3	50% cover of mixed *Acanthophora spicifera* & *Gracilaria salicornia;* small amount of *Montipora capitata* & *Dictyosphaeria cavernosa* in medium grained sand in vicinity of relict Kokokahi pier.
Btw	3	Abundant *Gracilaria salicornia* & *Acanthophora spicifera,* some *Montipora capitata, Caulerpa sertularioides, Sabellastarte spectabilis & Dictyosphaeria cavernosa* in coarse grained sand. At or around the 1500 ft mark, *Gracilaria salicornia d*ominance replaced by *Acanthophora spici fera*
2000	4	Reef margin quickly grades from ~70% live coral cover to <5% coral cover and abundant *Gracilaria salicornia* on sand.
Btw	3	Across reef about 50 ft outside from Sta. 2000 live coral increases, abundant *Montipora capitata & Porites compressa, Sabellastarte spectabilis* & *Gracilaria salicornia,* moderate *Dictyosphaeria cavernosa, Dendostrea sandvicensis, Phallusia nigra & Halichondria caerulea*
2500	29	Silt, numerous burrow openings.
3000	31	Silt, numerous burrow openings
3500	35	Silt, numerous burrow openings
4000	36	Silt, numerous burrow openings
4500	35	Silt, numerous burrow openings
5000	37	Silt, numerous burrow openings (joins Blue Line)

Btw = On Green route between the stations before (above) and after (below).

The distributions of these organisms along the Blue and Green routes are shown in Tables 4 and 5. As previously noted, reef corals and associated organisms were abundant on the Blue route only at Stas. 6000 to 7000 along a series of linear bottom features separated by linear sand patches. These are old dredging scars and very evident in aerial photographs like Fig. 3, above. This area was also the location of most of the reef fish sighted along the Blue Line,

Table 3. A listing of marine organisms recorded in the surveys.

Taxon	Group	*Genus_Species*	Status
Algae	Blue-green Algae	*Leptolyngula crosbyana*	Native
		Lyngbya majuscula	Native
		Symploca hydnoides	Native
	Green Algae	*Avrainvillea amadelpha*	Introduced
		Caulerpa sertularioides	Native
		Caulerpa racemosa	Native
		Cladophora sp.	Native
		Dictyosphaeria cavernosa	Native
		Dictyosphaeria versluysii	Native
		Enteromorpha sp.	Native
		Halimeda sp.	Native
	Brown Algae	*Hydroclathrus clathratus*	Native
	Red Algae	*Acanthophora spicifera*	Introduced
		Ceramium sp.	Native
		Gracilaria cornopfolia	Native
		Gracilaria salicornia	Introduced
		Hypnea musciformis	Introduced
		Spyridia filamentosa	Introduced
Flowering Plants	Seagrass	*Halophila hawaiiana*	Endemic
	Mangrove	*Rhizophora mangle*	Introduced
Invertebrates	Sponges	*Biemna fistulosa*	Cryptogenic
		Callyspongia sp.	Native
		Halichondria caerulea	Introduced
		Mycale grandis	Introduced
	Corals	*Pocillopora damicornis*	Native
		Porites compressa	Endemic
		Montipora capitata	Native
	Anemones	*Aiptasia sp*	Native
		Boloceroides mumurrichi	Native
		Gyractis sesere	Native
	Molluscs	*Crassostrea sp.*	Introduced
		Ctena bella	Native
		Dendostrea sandvicensis	Native

Table 3 (continued).

Taxon	Group	*Genus_Species*	Status
	Molluscs (cont.)	*Hypselodoris infurcata*	Native
		Lioconcha hieroglyphica	Native
		Plakobranchus ocellatus	Native
		Trochus sp.	Native
		Trochus intextus	Native
		Vermetus alii	Introduced
	Polychaetes (Worms)	*Sabellastarte spectabilis*	Introduced
		Mesochaetopterus sagittarius	Native
		Spirobanchus giganteus	Native
	Crustaceans	*Alpheus rapax*	Native
		Calappa hepatica	Native
		Chthamalus proteus	Introduced
		Thalamita sp.	Introduced
		Scylla serrata	Introduced
		Platypodia eydouxii	Native
		Pilodius areolatus	Native
		Metopograpsus thukuhar?	Native
	Tunicates	*Ascidia sydneiensis*	Introduced
		Botryllus sp.	Native
		Didemnum sp.	Native
		Phallusia nigra	Introduced
Marine Fish	Blennies	*Cirripectes obscurus*	Native
	Butterflyfish	*Chaetodon miliaris*	Endemic
	Cardinalfish	*Apogon sp.*	Native
		Foa brachygamma	Native
	Damselfish	*Abudefeduf abdominalis*	Endemic
		Abudefdef vaigiensis	Native
		Dascyllus albisella	Endemic
	Gobies	*Asterropteryx semipunctatus*	Native
		Psilogobius mainlandi	Endemic

Table 3 (continued).

Taxon	Group	*Genus_Species*	Status
	Jacks	*Caranx melampygus*	Native
		Scomberoides lysan	Native
	Parrotfish	*Scarus psittacus*	Native
	Pufferfish	*Arothron hispidus*	Native
	Surgeonfish	*Acanthurus blochii*	Native
		Acanthurus leucopareius	Native
		Acanthurus triostegus	Native
		Zebrosoma veliferum	Native
	Wrasses	*Thalassoma duperrey*	Endemic

resulting in the highest numbers of species (16-23) found for any Blue Line stations. Further shoreward, towards ʻAikahi from this flourishing community, the reef flat is mostly sand without live coral and is dominated in different areas by the introduced algae, *Gracilaria salicornia* and A*canthophora spicifera*, or large clumps of hairlike *Lyngbya majuscula,* with some occurrences of the blue-green alga, *Symploca hydenoides*, and the brown alga, *Hydroclathrus clathratus*. A small patch of the endemic sea-grass, *Halophila hawaiiensis*, was noted on the reef flat at Sta. 8500, but a much larger bed occurred offshore of Sta. 7500 and another small bed between Stas. 6500 and 7000. Another small sea-grass bed occurred on the sand flat near the Kāneʻohe shore at the Sta. 500, which was the only notable species to be found in this area shoreward of the deep silt that comprised the bottom from Stas. 1000 to 5500 along the Blue Line.

The distribution of species along the Green Line alternative also showed the previously noted limitation on reef coral growth and associated reef organisms, here found at Stas. 1500 and 2000. Stations further seaward had only deep silt bottom (with burrow openings). The reef outside of Green Line Sta. 2000 had high coral cover approaching that at Stas. 6000 to 7000 on the Blue Line. This area also had a diverse fish assemblage, giving a total of 30 species when those associated with the nearby reef face are included. Numbers of species decreased shoreward to 10 species at Sta. 1500 and then increased to 23 species at Sta. 1000, but the reef flat there was still dominated by a mixed assemblage of macroalgae. Algal coverage then decreased with approach to the shore off Kokokahi.

Table 4. Occurrences of organisms at stations along Blue Line route.

			Distance (ft) x1000																			
Group	Taxa	Species	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
Indet.		Burrows in silt			x	x	x	x	x	x	x	x	x									
Algae	Blue Green	*Leptolyngula crosbyana*															x					
		Lyngbya majuscula	x											x	x	x	x		x			
		Symploca hydnoides															x		x	x		
	Brown	*Hydroclathrus clathratus*														x	x					
	Chlorophyta	*Enteromorpha sp.*															x					
	Green	*Avrainvillea amadelpha*	x																			
		Cladophora sp.															x					
		Dictyosphaeria cavernosa												x	x	x	x		x			
		Dictyosphaeria verslusyii													x							
		Halimeda sp.		x																		
	Red	*Acanthophora spicifera*	x	x											x	x	x	x	x			
		Ceramium sp.	x																			
		Gracilaria parvispora															x					
		Gracilaria salicornia	x	x											x		x		x	x	x	x
		Hypnea musciformis	x														x					
		Spyridia filamentosa	x																			
Flowering Plants	Mangroves	*Rhizophora mangle*																			x	x

Table 4 (continued).

Group	Taxa	Species	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
			Distance (ft) x1000																			
Invertebrates	Sponges	*Black sponge*												x	x							
		Callyspongia sp.													x							
		Halichondria caerulea		x										x	x	x		x				
		Mycale grandis												x	x	x				x		
	Hydroids	*Pennaria disticha*															x					
	Anemones	*Aiptasia sp*															x					
		Boloceroides mumurrichi													x							
	Corals	*Montipora capitata*												x	x	x	x					
		Pocillopora damicornis														x						
		Porites compressa												x	x	x						
	Zoanthid	*Gyractis sesere*															x			x	x	
	Molluscs	*Ctena bella*																	x		x	
		Dendostrea sandvicensis												x	x	x			x			
		Lioconcha hieroglyphica																	x			
	Polychaetes	*Sabellastarte spectabilis*												x	x	x			x	x		
		Spirobanchus giganteus																	x			
	Crabs	*Calappa hepatica*																		x		
		Pilodius areolatus														x						
		Scylla serrata	x																			
	Alpheid Shrimp	*Alpheus rapax*																	x		x	
	Echinoderms	*Opheodesoma spectabilis*																	x	x		

Table 4 (continued).

Group	Taxa	Species	Distance (ft) x1000																			
			0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
	Tunicates	*Didemnum* spp.															x		x	x		
		Phallusia nigra													x	x						
Marine Fishes	Blennies	*Cirripectes obscurus*														x						
	Cardinalfish	*Apogon sp.*														x						
		Foa brachygamma														x						
	Damselfish	*Abudefeduf abdominalis*													x							
		Dascyllus albisella													x	x						
	Gobies	*Asterropteryx semipunctatus*													x	x						
		Psilogobius mainland	x																			
		Psilogobius mainlandi														x			x	x	x	
	Parrotfish	*Scarus psittacus*													x							
	Pufferfish	*Arothron hispidus*														x			x	x	x	x
	Surgeonfish	*Acanthurus blochii*													x							
		Acanthurus leucopareius													x	x						
		Zebrosoma veliferum													x	x						
		Total Taxa	10	4										9	23	23	16	2	16	10	7	3

Table 5. Occurrences of organisms at stations along Green Line route.

			Distance (ft) x1000								
Group	Taxa	Species	1	1.5	2	2.5	3	3.5	4	4.5	5
Indet,		Burrows in silt				x	x	x	x	x	x
Algae	Bluegreen Algae	*Lyngbya majuscula*	x		x						
	Green Algae	*Caulerpa racemosa*	x		x						
		Caulerpa sertularioides	x		x						
		Dictyosphaeria cavernosa		x	x						
	Red Algae	*Acanthophora spicifera*	x	x	x						
		Ceramium sp.			x						
		Gracilaria salicornia	x	x	x						
Invertebrates	Anemones	*Gyractis sesere*	x		x						
	Corals	*Montipora capitata*		x	x						
		Porites compressa			x						
	Crustaceans	*Alpheus rapax*	x		x						
		Calappa hepatica	x								
		Chthamalus proteus		x							
		Crassostrea sp.		x							
		Platypodia eydouxii	x								
	Molluscs	*Dendostrea sandvicensis*	x		x						
		Hypselodoris infurcata	x		x						
		Mesochaetopterus sagittarius	x								
		Plakobranchus ocellatus	x								
		Trochus intextus			x						
		Trochus sp.	x								
		Vermetus alii		x							
	Polychaetes	*Sabellastarte spectabilis*	x		x						
		Spirobanchus giganteus			x						
	Sponges	*Biemna fistulosa*	x								
		Halichondria caerulea			x						
		Mycale grandis	x	x	x						
		Yellow Green Sponge	x								
	Tunicates	*Ascidia sydniensis*			x						
		Bottryllus sp.		x	x						
		Didemnum sp.	x	x							
		Phallusia nigra			x						
Marine Fishes	Damselfish	*Abudefeduf abdominalis*			x						
	Gobies	*Asterropteryx semipunctatus*	x		x						
		Psilogobius mainlandi			x						
	Jacks	*Caranx melampygus*			x						
		Scomberoides lysan			x						
	Parrotfish	*Scarus psittacus*			x						
	Pufferfish	*Arothron hispidus*	x								
	Surgeonfish	*Acanthurus blochii*	x		x						
		Acanthurus triostegus	x		x						
	Wrasses	*Thalassoma duperrey*			x						
Total			23	10	30	1	1	1	1	1	

Quantitative Transect Surveys

Taxa and substrata occurring on or adjacent to each transect are listed in Tables 6 through 8, which give percent cover if the parameter was sufficiently abundant to be detected by the 50-point intercept method, or presence (p) if it was in low abundance. Based on their locations and similarities of benthic cover and species composition, the 19 transects are placed into one of three groups. Figure 6 is a graphical presentation of average total cover for macroalgae, sea grass, corals, other invertebrates, and the various types of substrata for each transect segment.

Table 6 lists coverage and presence for organisms for transects near the Kāneʻohe shoreline: Blue Line (BL) stations just off the shore (within 500 ft from the origin) and Green Line (GL) reef flat stations from the shore out 2000 ft from the origin (and including a Green Line transect on the reef slope near Sta. 2000). The Blue Line sites were all covered by silt, sand or pebbles/gravel with only a small amount of macroalgae present. Benthic cover at Stas. GL 1000 and GL 1500 was mostly mixed *Gracilaria saliconia*, *Acanthophora spicifera*, and *Lynbya majuscula* totaling 26 to 38% cover at Sta. GL 1000 and 65 to 70% at Sta. GL 1500, with a few sponges and tunicates present. The character of the benthic assemblage on the reef flat changed dramatically with approach to the reef slope near Sta. GL 2000, where corals—entirely *Montipora capitata* and *Porites compressa*—totaled 10 to 40% cover, and the introduced orange keyhole sponge, *Mycale grandis*, and the featherduster worm, *Sabellastarte specatibilis*, were abundant enough to total 2 to 6% cover. However, the dominant benthic organism was invasive, *G. salicornia*, which composed nearly all of the algal cover, totaling 34 to 65% of the bottom. Both coral and algal cover decreased substantially on the reef slope just beyond Sta. GL 2000 and silt, which ranged from 61 to 67%, was the dominant bottom cover on the transect followed by *G. saliconia* at 19 to 23%, and total coral at 8 to14%.

All station locations not appearing in Tables 6, 7, or 8 are on silt bottom, 26 to 42 ft (8 to 13 m) deep, outside of the reef line (lagoonal). The three stations starting at BL 6000 (Table 7 and Fig. 6) are adjacent to linear dredge marks that extend in a northeast–southwest direction, with high coral cover and associated reef organisms that are unique compared to the rest of the locations along the potential pipeline alignments. Total coral cover at these three stations ranged from 50 to 80%, dominated by *M. capitata* and *P. compressa*, the two most abundant coral species in Kāneʻohe Bay. *Pocillopora damicornis* was also present in the vicinity of Stas. 6000 and 7000. The invasive orange keyhole sponge and the featherduster worm were next most abundant, with mean cover values of 0.4 to 4.4%. Many other invertebrates were recorded at these three stations that were not noted elsewhere, but macroalgae was rare, with *G.*

salicornia abundant enough to be recorded as 1.4% along one transect segment at Sta. 7000. The substratum was primarily silt with a substantial amount of coral rubble.

Table 6. Percent cover or presence of benthic organisms on the Blue Line (BL) and Green Line (GL) reef transects.

	BL Shore		BL 500		GL Shore		GL 1000		GL 1500		GL 2000		GL 2000†	
Category/Species	A	B	A	B	A	B	A	B	A	B	A	B	A	B
MACROALGAE		2.8	3.5			6.4	37.8	26.0	69.6	65.1	64.8	34.2	22.7	19.2
Acanthophora spicifera			3.5			3.6	23.6	17.2	16.9	37.6				0.2
Caulerpa taxifolia							p							
Caulerpa sertularioides							p							
Dictyospheria cavernosa							p				1.3	0.7	0.0	
Dictyospheria versluysii									p					
Gracilaria burstoperis											p			
Gracilaria salicornia		1.2				2.8	14.2	8.8	44.0	13.9	63.6	33.3	22.4	18.4
Lynbya majuscula									2.7	8.7		0.2	p	0.5
Other Macroalgae		1.6												
CORAL											9.5	40.0	13.7	8.1
Montipora capitata									p	p	6.4	25.3	12.4	12.4
Porites compressa									p	p	3.1	14.7	1.4	1.4
OTHER INVERTEBRATES						0.4					2.2	6.5	7.1	5.4
PORIFERA														
Biemna fistulosa											p		p	
Halochondria coerulea							p		p		p		p	
Mycale grandis											0.2	0.8	0.8	
Other Porifera		0.4									2.0	2.0	2.5	5.4
CNIDARIA														
Boloceroides mumurrichi									p					
Zoanthus sp. (green)							p							
MOLLUSCA														
Chromodoris decora													p	
Dendostrea sandvicensis														
Serpulorbis variabilis											p			
POLYCHAETA														
Mesochaetopterus sagittarius								p						
Sabellastarte spectablis							p		p		0.0	3.7	3.7	
CRUSTACEA														
Portunidae unid. sp.	p													

Table 6 (continued).

Category/Species	BL Shore A	BL Shore B	BL 500 A	BL 500 B	GL Shore A	GL Shore B	GL 1000 A	GL 1000 B	GL 1500 A	GL 1500 B	GL 2000 A	GL 2000 B	GL 2000† A	GL 2000† B
TUNICATA														
Ascidia sydniensis									p		p			
Botryllus sp. (red)									p					
Herdmania momus							p						p	
Phallusia nigra							p		p		p		p	
Didemnum sp. (white)	p						p				p			
SUBSTRATUM	100	96.8	96.5	100	100	93.2	62.2	74.0	29.2	34.1	23.5	21.0	61.0	67.4
Coral Rubble							0.4	2.8	0.0	1.2	9.1	0.2	0.2	2.2
Dead Coral											13.5	20.5	12.4	5.7
Sand			20.2	22.4		88.0	61.8	71.2	29.2	32.9	0.9	0.0	0.0	0.0
Silt	100	96.4	76.3	77.6								0.2	48.4	59.5
Pebbles/Gravel		0.4			100	5.2								

Note: "A" and "B" are results from two 10 m segments at either end of the same 25 m transect.
† - reef slope transect; others are in reef flat areas. p – present in low numbers.
Values in gray boxes are sums for the category.

Table 7. Percent cover or presence of benthic organisms on Blue Line (BL) deep bottom and reef slope transects.

Category/Species	BL 6000 5A	BL 6000 B	BL 6500 4A	BL 6500 B	BL 7000 3A	BL 7000 B	BL 7000 † 6A	BL 7000 † B	BL 7500 2A	BL 7500 B	BL 7500 † 1A	BL 7500 † B
MACROALGAE		0.4	0.0	0.0	1.4	0.0	23.1	11.2	30.5	48.1	29.1	36.3
Acanthophora spicifera									0.4			
Dictyospheria, cavernosa									0.7			
Dictyospheria versluysii	p		p									
Gracilaria salicornia			p		1.4	0.0	23.1	11.2	28.0	47.5	28.0	36.1
Lynbya majuscula	p		p				p		1.4	0.6	1.1	0.2
Other Macroalgae		0.4										
SEAGRASS							14.6	21.0				
Halophila hawaiiana							14.6	21.0				
CORAL	62.7	50.5	79.2	79.7	50.1	54.3					1.0	
Pocillopora damicornis	p				p							
Montipora capitata	17.1	15.4	58.3	23.8	35.4	37.8	p		p			
Porites compressa	45.5	35.1	20.8	55.9	14.7	16.5					p	
OTHER INVERTEBRATES	1.4	3.1	6.3	6.1	0.8	0.4						
PORIFERA												
Biemna fistulosa	p		p									
Callyspongia sp.	p		p								p	
Gelloides fibrosa	p		p		p							
Halochondria coerulea	p		p		p						p	
Mycale grandis	0.6	1.9	4.2	2.0	0.4	0.4					p	

Table 7 (continued).

Category/Species	BL 6000 5A	B	BL 6500 4A	B	BL 7000 3A	B	BL 7000 † 6A	B	BL 7500 2A	B	BL 7500 † 1A	B
CNIDARIA												
Aiptasia sp.	p		p		p							
MOLLUSCA												
Dendostrea sandvicensis	p		p		p							
Serpulorbis variabilis	p											
Vermetus alii	p		p		p							
NEMERTINA												
Baseodiscus cingulatus									p			
POLYCHAETA												
Loimia medusa					p							
Sabellastarte spectablis	0.8	1.2	2.1	4.1	0.4							
CRUSTACEA												
Alpheus sp.									p			
Pilodius areolatus	p		p		p							
TUNICATA												
Botryllus sp. (red)			p		p						p	
Herdmania momus	p		p		p							
Phallusia nigra	p		p		p							
Didemnum sp. (white)	p				p							
SUBSTRATUM	35.9	28.2	14.6	14.2	47.6	45.2	62.1	67.7	69.5	51.9	70.9	63.7
Coral Rubble	1.0	3.7			4.0	2.9			13.0	3.0	8.7	16.5
Dead Coral	15.5	10.4	10.4	7.2	18.2	8.5		0.2			0.4	
Sand		3.7		0.2			61.9	67.5	56.6	48.7	61.6	47.2
Silt	19.4	10.4	4.2	6.7	25.4	33.9	0.2			0.2	0.2	

Note: "A" and "B" are results from two 10 m segments at either end of the same 25 m transect.
† - reef slope transect. Others are in deeper bottom areas. p – present in very low numbers.
Values in gray boxes are sums for the category.

Table 8. Percent cover or presence of benthic organisms on ʻAikahi Blue Line (BL) reef transects.

Category/Species	BL 8000† A	B	BL 8500† A	B	BL 8500 A	B	BL9000 A	B	BL9500 A	B	BL10000 A	B
MACROALGAE	13.0	24.6	6.0	3.6	7.2	7.6	25.6	32.0	32.0	22.4	71.6	92.0
Acanthophora spicifera	0.2	0.8		0.2							6.4	0.4
Caulerpa sertularioides	p											
Dictyospheria, cavernosa					p							
Gracilaria salicornia	9.5	21.4	1.2	2.6	6.0	6.8	25.6	32.0	32.0	22.4	71.6	92.0
Lynbya majuscula	3.5	2.4	4.8	0.8	1.2	0.8						
SEAGRASS			0.4	2.9								
Halophila hawaiiana			0.4	2.9								

Table 8 (continued).

Species	BL 8000†		BL 8500†		BL 8500		BL9000		BL9500		BL10000	
	A	B	A	B	A	B	A	B	A	B	A	B
CORAL		0.6										
Montipora capitata	p	0.6										
Porites compressa	p											
OTHER INVERTEBRATES	27.6	12.7										
Callyspongia sp.	p											
Gelloides fibrosa	p											
Halochondria coerulea	p		p									
Mycale grandis	p	0.7										
Other Porifera	27.6	12.0										
CNIDARIA												
Aiptasia sp.	p											
MOLLUSCA												
Vermetus alii	p											
Sabellastarte spectablis							p					
CRUSTACEA												
Alpheus sp.	p										p	
Gonodactylaceus falcatus											p	
Palaemon/Palemontes sp.						p						
Portunidae unid. sp.									p		p	
TUNICATA												
Ascidia sydniensis	p											
Herdmania momus	p											
Didemnum sp. (white)	p				p							
ECHINODERMATA												
Opheodesoma spectabilis					p		p					
SUBSTRATUM	59.4	61.9	92.7	93.5	92.4	92.0	74.4	68.0	68.0	77.6	22.0	7.6
Coral Rubble			0.4		1.2	1.6	4.0	2.0	8.4	20.0	0.8	1.2
Dead Coral	12.0	0.4										
Sand		0.2	92.3	93.5	91.2	90.4	70.4	66.0	59.6	57.6		
Silt	47.4	61.2									21.2	6.4

Note: "A" and "B" are results from two 10 m segments at either end of the same 25 m transect.
† - reef slope transect. Others are in shallow, reef flat areas. p – present in low numbers.
Values in gray boxes are sums for the category.

Immediately beyond Sta. 7000, the pipeline route curves towards shore and encounters a tongue of reef that extends outward to the northwest, adjacent to a natural channel coinciding with Sta. 8000 (Table 8). The slope between Sta. 7000 and Sta. 7500 on the reef flat is very gradual and was the location of the only substantial seagrass bed encountered on the surveys. *Halophila hawaiiensis*—the only endemic seagrass in Hawaiʻi—was abundant near Sta. 7000, with mean cover of 15-21%, growing on a sand bottom; the only

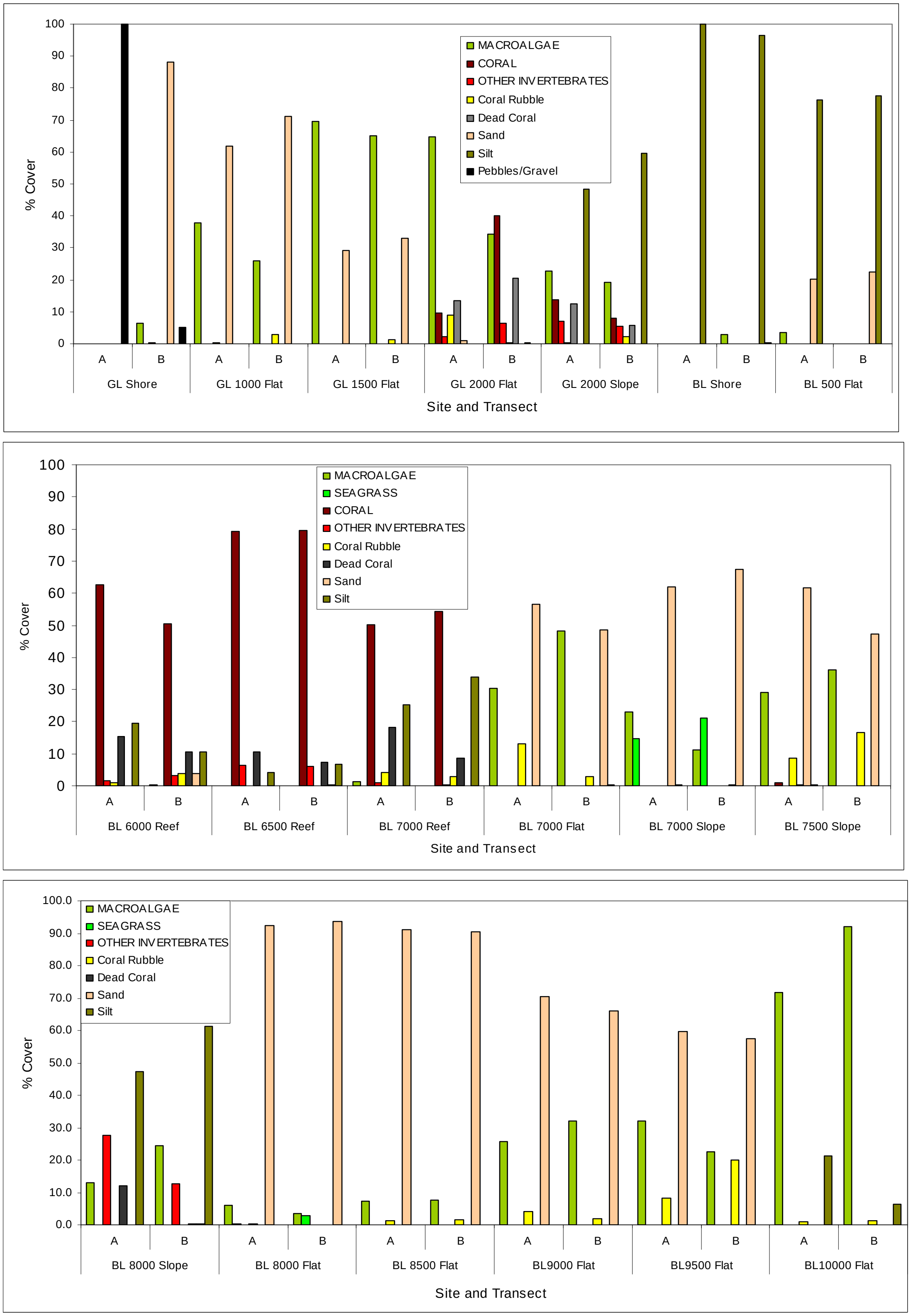

Figure 6. Percent cover on transects by taxonomic group or substratum type. **top**: Kāneʻohe BL and GL reef transects; **middle**: BL reef and slope transects; **bottom:** ʻAikahi reef BL transects.

other macro-organisms noted were *G. salicornia* at 11 to 21% and *L. majuscula* and *M. capitata* present. The reef flat above this slope at Sta. 7500 is dominated by *G. salicornia* with a small component of *A. spicifera, L. majuscula,* and *D. cavernosa* totaling 30 to 40%, with a small amount of *M. capitata* coral present. Similar conditions were found on the Sta. 7500 slopes on the other side of the tongue of reef. *G. salicornia and L. majuscula* totaled means of 29 to 36% of total bottom area and a few isolated colonies of *M. capitata* and sponges occur.

The reef slope beyond Sta. 8000 has intermediate algal cover of 13 to 25% of mostly *G. salicornia,* with some *L. majuscula* and *A. spicifera,* rare *M. capitata* coral, and a relatively high cover of a variety of sponges that are able to utilize the high particulate levels that occur in the turbid water at this site. The bottom at this site is composed of mixed dead coral rubble and silt. Going shoreward from this point towards ʻAikahi, the transects reflect a highly degraded reef flat environment that becomes increasingly dominated towards shore by *G. salicornia* on sand substratum. On the flat nearest Sta. 8000, even algae are in low abundance, averaging only 3.6 to 6% on the transect, increasing to 7.2 to 7.6% at Sta. 8500. Coverage at both sites is composed of *G. salicornia* and *L. majuscula*. *G. salicornia* was the only algal species counted on transects from Stas. 9000 and 9500, where the species averaged 22 to 32%, to Sta. 10000 nearshore, where this species occupied 72 to 92% of the available space on the bottom.

Sediment Infauna

Only algal thalli, and those very rarely, were seen attached on the bottom during underwater surveys (Fig. 4). However, an abundance of burrow openings occur and a few burrows were observed to be occupied by alpheid shrimp or goby fish. Crab tracks were evident on the surface. The number of burrows at each connection site was based upon 10 quadrat placements per site. Burrow densities were highly variable in these quadrats, both within and between sites. Mean number of burrows/m^2 ranged from 12 to 63 with minima as low as 2 and maxima as high as 150/m^2 (Table 9).

Attempts to sample the sediment infauna at five sites by divers inserting a 28 cm diameter cylinder 35 cm into the sediment and capping the cylinder from below were unsuccessful in obtaining organisms, possibly because the sampling process induced motile organisms to escape into complex burrow systems. Information is available for sediment macrofauna densities and biomass from two sources where sampling was previously done in South Kāneʻohe Bay. Both studies (Harrison, 1981; Bush, 2003) utilized a combination of airlift and poisoning at the surface of burrows to sample the top 30-35 cm of sediments.

Table 9. Summary results for benthic burrow opening counts.

				Burrows per sq. meter				
Line	Station	Box Dimensions (ft)	Depth (ft)	Avg	Std Dev	Min	Max	*n*
Green	2000	50 x 50	29	58	±24	24	96	*10*
Blue	2000	50 x 50	26	12	±6	2	20	*10*
Blue	2500	50 x 50	32	55	±33	10	126	*10*
Blue	3500	200 x 200	36	77	±47	24	150	*10*
Blue	4500	100 x 100	35	63	±32	20	120	*10*
Blue	5500	200 x 200	42	91	±32	22	136	*10*
Blue	8000	50 x 50	28	84	±30	42	142	*10*
			Overall	63	±26	2	150	*70*

The dominant resident organism in both studies was the alpheid snapping shrimp, *Alpheus mackayi*, which Harrison (1981) found in densities of (mean±sd) of 12±4/m^2 by poisoning and 14±5/m^2 by airlift sampling in the south Bay during the period when eutrophication and high densities of benthic filter and deposit feeders characterized the south Bay. Organisms sampled were those retained by a 3 mm mesh screen. Alpheids were estimated to be 78% of the mean total biomass of 5.1 g/m^2 determined from poisoning or 48% of the total 8.8 g/m^2 determined by airlift sampling, suggesting that poisoning was less effective than airlifting for getting a complete sample of the sediment infauna. Harrison also noted burrow densities of up to 450/m^2, with an average of about 100/m^2 throughout the bay.

Sampling by Bush (2003) in 1995, conducted approximately 20 years after Harrison's (1981) sampling, and 18 years after sewage release in Kāneʻohe Bay ended in 1977, found substantially lower *A. macayi* densities of only 3.6±5.2/m^2, or only about 25% of the densities found by Harrison. Bush's samples were of the organisms retained on a 1.5 mm mesh screen, smaller than that used by Harrison. Other macrofauna captured were the crab, *Podophthalmus vigil* (1.3±2.4/ m^2), collected by airlift, the goby, *Oxyruricthys lonchatus* (2.3±0.7/ m^2) sampled by poisoning, and the goby, *Hazeus nephodes* (2 to 3/m^2), estimated visually. Bush (2003) concluded that the lower infaunal densities were due to the cessation of sewage discharge and resulting lower availability of food. But this did not consider the finding that higher alpheid densities were found by Harrison (1981) in the north and central Bay than in the south Bay, beyond the zone where sewage related eutrophication was considered to be impacting water quality and organic enrichment.

Sediment Meiofauna

A total of 1,706 invertebrates belonging to 53 taxa, including 329 polychaetes representing 37 taxa were identified for the meiofaunal samples collected from three environments: shallow reef flat, stream mouth, and lagoon bottom. Lists of identified taxa, their locations of occurrence, trophic category, and motility are in the detailed report attached as Appendix C.

Figure 8 shows total number of taxa and total polychaete taxa identified for the three sampling locations and Fig. 9 shows total numbers of individuals and numbers by major taxonomic category. Both graphs indicate clear differences in numbers of taxa and individuals among the three environments sampled. Samples collected from the reef flat had the highest invertebrate abundance and greatest number of species. A total of 1,090 invertebrates from 58 taxa were found on the reef flat, and 231 of those invertebrates were polychaete worms from 34 taxa. Samples from the stream mouth contained 520 invertebrates from 40 taxa, 89 of which were polychaetes from 20 taxa . Samples collected from the lagoon floor contained 96 invertebrates from 10 taxa, 9 of which were polychaetes from only five taxa.

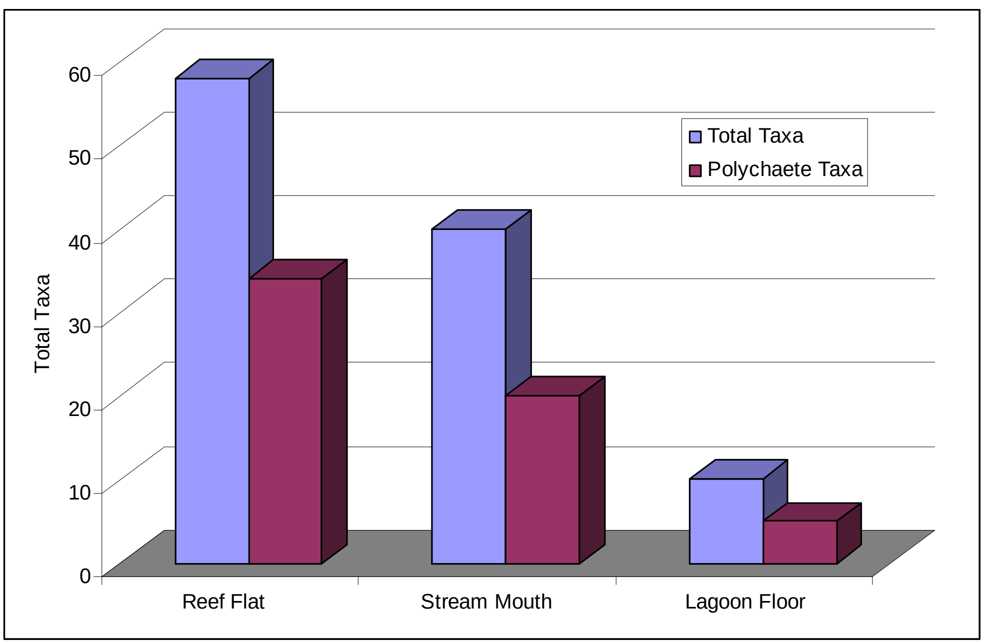

Figure 8. Numbers of total and polychaete taxa for the three environments sampled.

The infaunal community is dominated in number by nematodes on the reef flat and the lagoon bottom, but by oligochaetes at the stream mouth. The results indicate that the meiofaunal community inhabiting the fine sediments of the lagoon floor are highly depauperate compared to the community inhabiting the coarser sands of the reef flat or the silty sediments off of the mouth of Kāneʻohe Stream.

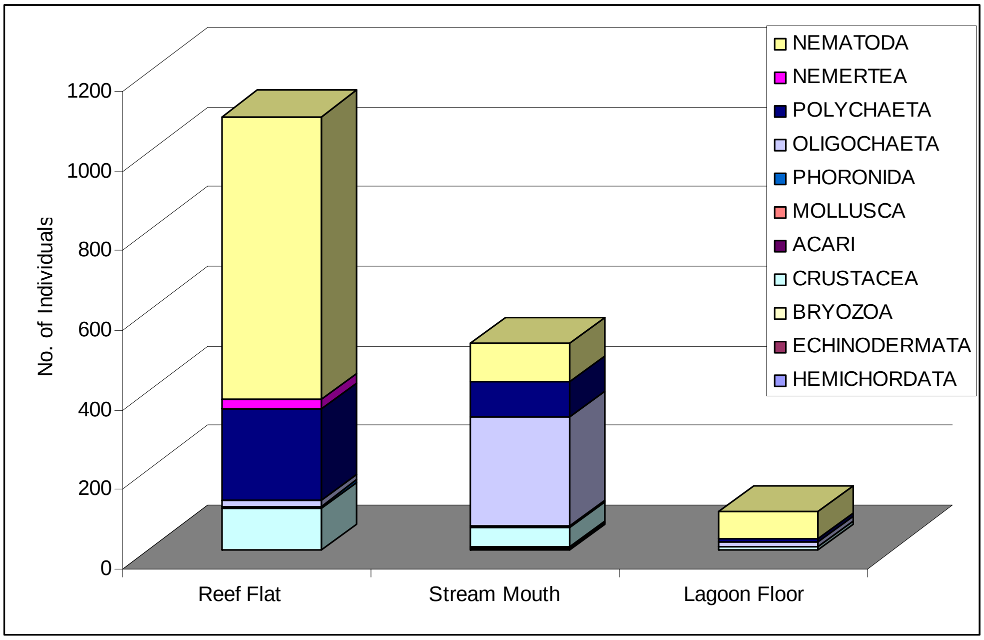

Figure 9. Numbers of individual taxa within major taxonomic groups and totals for the three environments sampled.

Reef Fishes

The fish species counted and lengths estimated at the benthic transect sites are listed in Table 10a-c and shown graphically in Figure 10, which includes total numbers of fish individuals, numbers of species, biomass per transect, and extrapolated biomass in kg/ha. Only 15 species were recorded for all of the sites, and numbers of species were very sparse at all except Blue Line Stas. 6000 and 6500, where more than 110 individuals were counted, and Stas. 7500 and 8000 (reef slopes), where 43 to 52 fishes were counted. By contrast, only three species with 11 individuals occurred at Sta. 7000, where the most abundant species on other transects, the goby *Asterropteryx semipunctatus*, was conspicuously absent. However, total biomass estimated at Sta. 7000 was much greater than any other location because of the presence of two *Bothus* sp flounders at 85 and 111 g estimated weight. Consequently biomass for this transect was about a third more than at Sta. 6000, nearly double that at Sta. 6500, and almost eight times the biomass at the two nearby reef slope stations.

Table 10a. Fish counts for nearshore sites off Kāneʻohe.

Species	BL Shore	BL 500 Flat	BL 1000 Flat	GL Shore	GL 1000 Flat	GL 1500 Flat	GL 2000 Flat	GL 2000 Slope
ACANTHURIDAE								
Acanthurus blochii							2	
Zebrasoma veliferum							3	
BLENNIDAE								
Cirripectes obscurus							1	
GOBIIDAE								
Asterropteryx semipunctatus							5	2
Psilogobius mainlandi				1	5	4		1
LABRIDAE								
Stethojulis balteata							1	
LUTJANIDAE								
Lutjanus fulvus		1						
POMACENTRIDAE								
Abudefduf abdominalis							1	
TETRADONTIDAE								
Arothron hispidus						1		
Total Individuals	0	1	0	1	5	5	13	3
Total species	0	1	0	1	1	2	6	2
Total biomass/transect (g)	0	2.3	0	1.9	5.5	6.5	20.1	3.1
kg/ha	0	0.9	0	0.8	2.2	2.6	8.1	1.2

Table 10b. Fish counts for reef flat and reef slope stations.

	6000 Deep	6500 Deep	7000 Deep	7000 Slope	7500 Flat	7500 Slope
ACANTHURIDAE						
Acanthurus blochii	3	9		1		7
Zebrasoma veliferum		1				
APOGONIDAE						
Foa brachygramma	4	3				2
BLENNIDAE						
Bothus sp.			2			
GOBIIDAE						
Asterropteryx semipunctatus	91	69		38		39
Gnatholepis anjerensis	1	3	1	4		3
Psilogobius mainlandi	3		8		12	

Table 10b (continued).

	6000 Deep	6500 Deep	7000 Deep	7000 Slope	7500 Flat	7500 Slope
POMACENTRIDAE						
Abudefduf abdominalis		11				1
Dascyllus albisella	1					
SCARIDAE						
Chlorurus spilurus		2				
Scarus psittacus	12	12				
TETRADONTIDAE						
Arothron hispidus	1					
Total Individuals	116	110	11	43	12	52
Total species	8	8	3	3	1	5
Total biomass/transect (g)	135.1	108.6	203.4	21.1	19.8	26.2
kg/ha	27.0	21.7	40.7	4.2	7.9	5.2

Table 10c. Fish counts for ʻAikahi nearshore sites

Species	8000 Slope	8000 Flat	8500 Flat	9000 Flat	9500 Flat	10000 Flat
GOBIIDAE						
Asterropteryx semipunctatus	5					
Gnatholepis anjerensis	2					
Psilogobius mainlandi	3	1	9	13	6	0
Total Individuals	10	1	9	13	6	0
Total species	3	1	1	1	1	0
Total biomass/transect (g)	14.2	1.0	17.1	18.9	14.3	0.0
kg/ha	5.7	0.4	6.8	7.6	5.7	0.0

Fishes were generally sparse on reef flat transects, with only 0 to 6 species, 0 to 13 individuals, and biomass values of no more than 7% of those determined for coral reef sites (109 to 201 kg/ha). Fish numbers and biomass reached zero near both the Kāneʻohe and ʻAikahi shores. Fishes on the reef flats were almost entirely the goby, *Psilogobius mainlandi*, inhabiting burrows in the sand. The virtual absence of larger reef fishes on the reefs is likely related to the almost total absence of habitat on the silt laden reef flat from the Kāneʻohe shore out to Sta. 1000 on the Blue Line, or the near monopolization of the bottom by invasive algae on the Green Line reef flat sites and on the Blue Line reef flat approaching the ʻAikahi shore.

Figure 10 also shows the kg/ha average values for the Main Hawaiian Islands (MHI) provided by Ivors Williams (Div. Aquatic Resources, DLNR, pers. comm.) and based on values from surveys made by a number of investigators around the Hawaiian Islands (Williams et al., 2008). The MHI mean value of 48.4 kg/ha

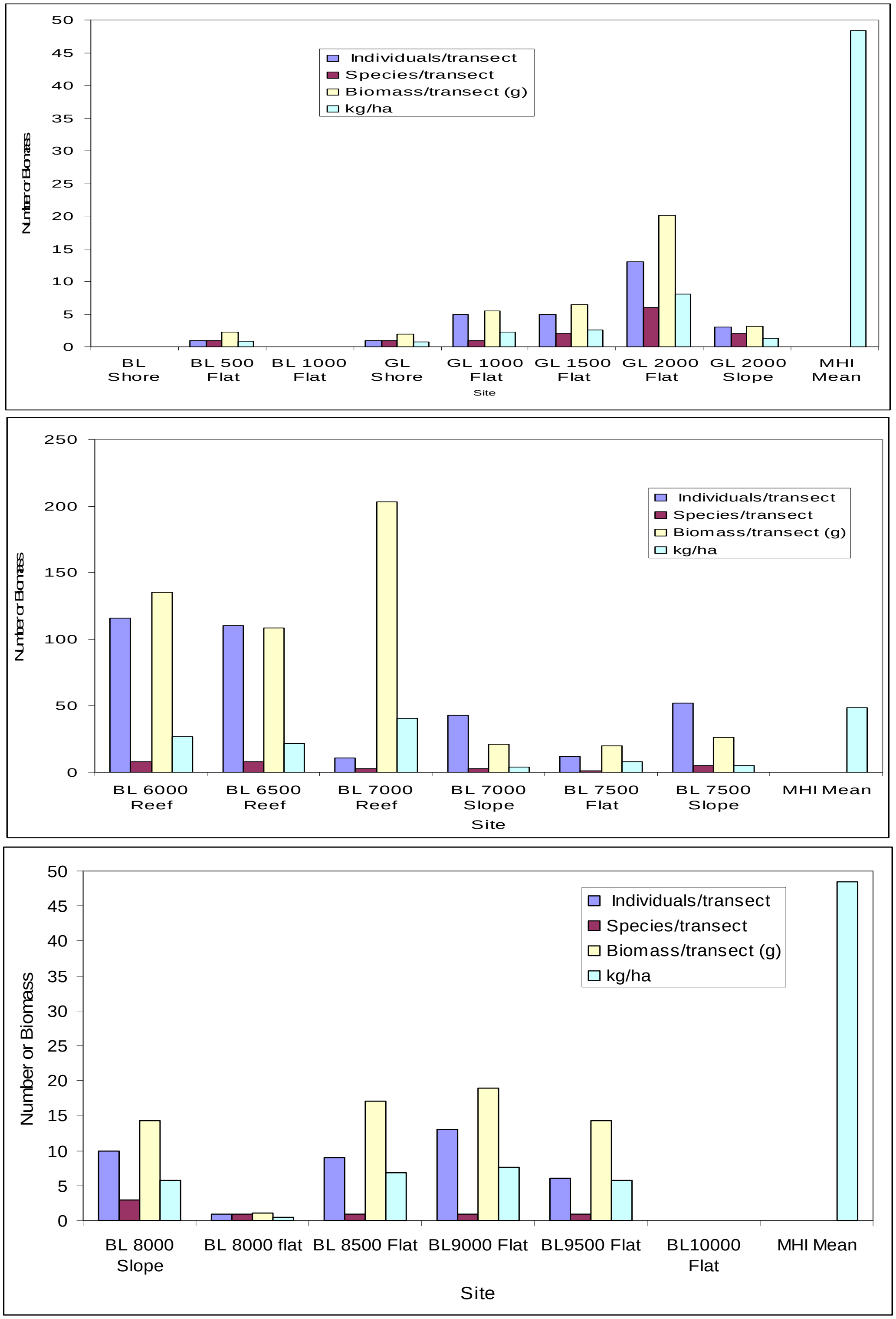

Figure 10. Fish numbers and biomass. Top: Kāne'ohe nearshore Blue and Green Line reef flats. Middle: Blue Line reef and slope. Bottom: 'Aikahi nearshore reef flat sites. Far right bar is the mean biomass value for the Main Hawaiian Islands.

is slightly more than the 40.1 kg/ha determined in the present study for Sta. 7000, and approximately double the values for the other two coral bottom sites. The MHI mean is at least five times the value for any reef flat or slope site on this survey, indicating that most of the fish populations along the pipeline routes are highly depauperate except on sites near or on flourishing coral bottom.

DISCUSSION

Listed Species and Species of Concern

No endangered or threatened (listed) species such as Hawaiian Monk seal or cetaceans were seen within the study area during field surveys from September through November, 2009. No previous reports could be found for Monk seal or wild cetaceans in south Kāneʻohe Bay during the approximately 60 years of operation of Hawaiʻi Institute of Marine Biology, or from any published source. Green sea turtles (*Chelonia mydas*; Aguirre et al., 1994; Zamzow, 1998; Balazs et al., 2000; Russell and Balazs, 2009) and, less commonly, Hawksbill turtles (*Eretmochelys imbricata*; Balazs, 1978) occur in Kāneʻohe Bay. On October 28, 2009, an *AECOS* biologist observed a solitary green sea turtle resting on the mud bottom adjacent to the 2000' transect survey location. The turtle was not observed foraging or swimming. A large Green sea turtle was seen on the fringing reef around Coconut Island in November 2009 (S. L. Coles, pers. obs.). It is therefore probable that sea turtles occasionally frequent the project area to utilize reef macroalgae as a food source

An additional species of concern to the National Oceanic and Atmospheric administration (NOAA) is the inarticulate brachiopod, *Lingula reevi*. This species was found to be very abundant in 1967-69 in the area of the present surveys by Worcester (1969), who found densities of up to 500/m^2 at sites on reef flats off the southeast shore of the Bay, one of these near the location of Sta. BL7500. No focused sampling for *L. reevi* was done in the present study, but recent studies describe that populations of this species have plummeted from the time when treated sewage and eutrophication was occurring in South Kāneʻohe Bay (Hunter et al., 2008, 2009). These surveys found that in 2004 the highest *L. reevi* densities in the same areas sampled in 1967-69 had fallen to 4/m^2, occurring only at the above mentioned location, and in 2007 no brachiopods occurred at this site and were also absent at eight of twelve sites where they were common to very abundant in the late 1960s. It is highly probable that these drastic reductions in *L. reevi* are due to the reduction in their food source since cessation of sewage into the bay in 1977. The prolific growth of invasive algae on the reef flats may also have contributed to the brachiopod decline. In any event, there is no likelihood of impact on this species from pipeline deployment operations.

Marine Community Sensitivity

The sensitivity of the marine communities along the Blue and Green pipeline routes are summarized in Table 11. Most of both the Blue and Green line routes are projected to be under areas of low sensitivity to potential environmental disturbance, either beneath soft lagoonal sediment with few infaunal organisms, or beneath already highly degraded reef flat areas dominated by invasive algae. Exceptions to these low sensitivity areas are the high to very high sensitivity coral reef locations at Stas. 6000 to 7000 and near Green Line Sta. 2000. Intermediate sensitivity areas are the seagrass beds on the Blue Line at Sta. 7000 to 7500 and reef slopes at Sta. 8000 to 8500.

Table 11. Station information on dominant organisms and their potential sensitivity to construction disturbance.

Station	Description	Dominant Benthic Biotope	Sensitivity
BL 1000	Silted flat off stream mouth	Meiofauna, few sponges	Low
BL1000-6000	Lagoon, silt/clay sediments	Meiofauna, alpheid shrimps	Low
BL 6000-7000	Coral reefs in medium sand	Abundant reef coral	Very high
BL 7000-7500	Seagrass in medium sand	Seagrass, few corals	Medium
BL 7500-8000	Reef slopes and sand flat	Invasive algae, few corals on slopes	Medium
BL 8000	Fine sand/silt	Meiofauna, alpheid shrimps	Low
BL 8000-8500	Reef slopes and sand flat	Invasive algae, few corals on slope	Medium
BL 8500-10000	Sandy reef flat	Sparce seagrass, abundant invasive algae	Low
GL Shore-2000	Sandy reef flat	Invasive algae	Low
GL 2000-2500	Reef edge	Moderate coral cover & invasive algae	High
GL 2500-5000	Lagoon, silt/clay sediments	Meiofauna, alpheid shrimps	Low

Subterranean slant drilling and pipe laying are the proposed methods for deploying the pipe well below the bottom of Kāneʻohe bay. Consequently there will be no direct impact on marine organisms from shore-based drilling and deployment activities. However, should emergency conditions require that in-water activities be conducted to complete the pipeline, Table 11 indicates that areas along the Blue Line from 6000 to 7000 and the Green Line from 2000 to 2500 ft should be avoided if at all possible.

Conclusions and Recommendations

The marine communities along most of the Blue and Green Line routes are on highly degraded reef flats or in fine sediments with much lower meiofauna densities than found in coarser sediments on nearby reef flats or even on the highly silted reef flat along the mouth of Kāneʻohe Stream. The benthic communities on most of the reef flat areas along the routes have few to no reef corals, few reef fish species or numbers (with very low biomasses), and very low species diversity. Assemblages are dominated by introduced invasive algae and a few filter feeding invertebrates such as sponges and tunicates. The only substantial coral bottom along the pipeline routes is from Stas. 6000 to 7000, where a series of low, linear outcrops support high coral cover and relatively high fish abundance. This area has recovered on a formerly dredged surface of the fringing reef. Another reef area showing moderate recovery from earlier documented degraded conditions is the reef flat near Green Line Sta. 2000 and on reef slopes near Blue Line Stas. 7500 and 8000, where some live coral is growing and intermediate values for fish counts and biomass were recorded. A large bed of endemic seagrass occurs between Stas. 7000 and 7500 that would be sensitive to excessive siltation.

Since pipeline deployment will be made by slant drilling and pipe extension from shorelines and the pipeline will be well below the ocean bottom for its entire distance, there is no potential impact to marine communities along the pipeline route from proposed construction activities. The proposed possible sites for emergency work is over the silt sand bottom that predominates along the pipeline route and is well removed from sensitive reef areas.

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Appendix A

Marine biota identified along the Green Line route in south Kāneʻohe Bay.

Taxa	Species	Green Line Stations								
		1000	1500	2000	2500	3000	3500	4000	4500	5000
Indet.	Burrows in silt				x	x	x	x	x	x
Algae										
Blue-green Algae	*Lyngbya majuscula*	x		x						
Green Algae	*Caulerpa racemosa*	x		x						
	Caulerpa sertularoides	x		x						
	Dictyosphaeria cavernosa		x	x						
Red Algae	*Acanthophora spicifera*	x	x	x						
	Ceramium sp.			x						
	Gracilaria salicornia	x	x	x						
Invertebrates										
Sponges	*Biemna fistulosa*	x								
	Halichondria caerulea			x						
	Mycale grandis	x	x	x						
	yellow-green sponge	x								
Anemones	*Gyractis sesere*	x		x						
Corals	*Montipora capitata*		x	x						
	Porites compressa			x						
Crustaceans	*Alpheus rapax*	x		x						
	Calappa hepatica	x								
	Chthamalus proteus		x							
	Crassostrea sp.		x							
	Platypodia eydouxii	x								
Molluscs	*Dendostrea sandvicensis*	x		x						
	Hypselodoris infurcata	x		x						
	Mesochaetopterus sagittarius	x								
	Plakobranchus ocellatus	x								
	Trochus intextus			x						
	Trochus sp.	x								
	Vermetus alii		x							

			Green Line Stations								
Group	Taxa	Species	1000	1500	2000	2500	3000	3500	4000	4500	5000
	Polychaetes	*Sabellastarte spectabilis*	x		x						
		Spirobanchus giganteus			x						
	Sponges	*Biemna fistulosa*	x								
		Halichondria caerulea			x						
		Mycale grandis	x	x	x						
		yellow-green sponge	x								
	Tunicates	*Ascidea sydneiensis*			x						
		Botryllus sp.		x	x						
		Didemnum sp.	x	x							
		Phallusia nigra			x						
		Fishes									
	Damselfish	*Abudefeduf abdominalis*			x						
	Gobies	*Asterropteryx semipunctatus*	x		x						
		Psilogobius mainlandi			x						
	Jacks	*Caranx melampygus*			x						
		Scomberoides lysan			x						
	Parrotfish	*Scarus psittacus*			x						
	Pufferfish	*Arothron hispidus*	x								
	Surgeonfish	*Acanthurus blochii*	x		x						
		Acanthurus triostegus sandvicensis	x		x						
	Wrasses	*Thalassoma duperrey*			x						
	Total Species		23	10	30	1	1	1	1	1	

Appendix B

Marine biota identified along the Blue Line route in south Kāne‘ohe Bay.

		Blue Line Distance (ft) x1000																			
Taxa	Species	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
	Burrows in silt			x	x	x	x	x	x	x	x	x									
Algae																					
Blue Green Algae	*Leptolyngbya crosbyana*															x					
	Lyngbya majuscula	x											x	x	x	x		x			
	Symploca hydnoides															x		x	x		
Brown Algae	*Hydroclathrus clathratus*														x	x					
Green Algae	*Enteromorpha sp.*															x					
	Avrainvillea amadelpha	x																			
	Cladophora sp.															x					
	Dictyosphaeria cavernosa												x	x	x	x		x			
	Dictyosphaeria versluyii													x							
	Halimeda sp.		x																		
Red Algae	*Acanthophora spicifera*	x	x											x	x	x	x	x			
	Ceramium sp.	x																			
	Gracilaria parvispora															x					
	Gracilaria salicornia	x	x											x		x		x	x	x	x
	Hypnea musciformis	x														x					
	Spyridia filamentosa	x																			
Flowering Plants																					
Mangroves	*Rhizophora mangle*																			x	x
Seagrass	*Halophila hawaiiana*	x												x	x			x			

Taxa	Species	Blue Line Distance (ft) x1000																			
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
	Invertebrates																				
Sponges	*Black sponge*												x	x							
	Callyspongia sp.													x							
	Halichondria caerulea		x										x	x	x		x				
	Mycale grandis												x	x	x				x		
Hydroids	*Pennaria disticha*															x					
Zoanthids	*Gyractis sesere*															x			x	x	
Anemones	*Aiptasia sp*															x					
	Boloceroides mcmurrichi													x							
Corals	*Montipora capitata*												x	x	x	x					
	Pocillopora damicornis														x						
	Porites compressa												x	x	x						
Crabs	*Calappa hepatica*																		x		
	Pilodius areolatus														x						
	Scylla serrata	x																			
Alpheid Shrimp	*Alpheus rapax*																	x		x	
Polychaetes	*Sabellastarte spectabilis*												x	x	x			x	x		
	Spirobanchus giganteus																	x			
Molluscs	*Ctena bella*																	x		x	
	Dendostrea sandvicensis												x	x	x			x			
	Lioconcha hieroglyphica																	x			
Echinoderms	*Opheodesoma spectabilis*																	x	x		
Tunicates	*Didemnum spp*															x		x	x		

		Blue Line Distance (ft) x1000																			
Taxa	Species	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
Tunicates	*Phallusia nigra*													x	x						
								Fishes													
Blennies	*Cirripectes obscurus*														x						
Cardinalfish	*Apogon sp.*														x						
	Foa brachygamma														x						
Damselfish	*Abudefeduf abdominalis*													x							
	Dascyllus albisella													x	x						
Gobies	*Asterropteryx semipunctatus*													x	x						
	Psilogobius mainlandi	x													x			x	x	x	
Parrotfish	*Scarus psittacus*													x							
Pufferfish	*Arothron hispidus*														x			x	x	x	x
Surgeonfish	*Acanthurus blochii*													x							
	Acanthurus leucopareius													x	x						
	Zebrosoma veliferum													x	x						
Total Species		**10**	**4**										**9**	**23**	**23**	**16**	**2**	**16**	**10**	**7**	**3**

Appendix B

***Water Quality Assessment for the Kailua – Kaneohe Force Main, Kaneohe Bay*, Oahu**
AECOS, Inc.
January 2010

Water Quality Assessment for the Kailua-Kaneohe Force Main, Kāneʻohe, Bay, Oʻahu.

January 29, 2010 *AECOS* No. 1215B

S. Allen Cattell
AECOS, Inc.
45-939 Kamehameha Highway, No. 104
Kāneʻohe, Hawaiʻi 96744
Phone: (808) 234-7770 Fax: (808) 234-7775 Email: aecos@aecos.com

Introduction

This report presents findings from a water quality sampling program for a proposed new Kailua–Kāneʻohe sewage force main. One proposed alternative includes construction of a subterranean pipeline extending below Kāneʻohe Bay, connecting the Kailua (ʻAikahi) and Kāneʻohe Wastewater Treatment Plants (WWTP). This pipeline would be installed using directional drilling from the land. There will be a need to dredged selected sites, isolated by sheet pilings, in order to connect sections of the pipe together (see *AECOS*, 2010 for more detail). *AECOS*, Inc was contracted by Austin Tsustumi and Associates, Inc. to assess water quality in the project area. This report presents the water quality data collected, compares the findings with water quality standards as set forth by the State of Hawaiʻi (HDOH, 2004), and briefly assesses potential impacts from the proposed project.

Background

Southern Kāneʻohe Bay was the receiving basin for increasing amounts of secondary treated effluents from the town of Kāneʻohe and primary sewage effluents from the Kāneʻohe Marine Corps Air Station (KMCAS) from the 1950s to the late 1970s, resulting in a general decline in water quality in this section of Kāneʻohe Bay (Caperon et al., 1971). The KMCAS WWTP discharged sewage at an outfall in the southeast corner of the Bay from 1951 through 1977. The Kāneʻohe WWTP discharged sewage at an outfall in the southern corner of the Bay from 1963 through 1977. In December 1977, the discharge from the

Kāneʻohe plant was permanently diverted to a deep ocean outfall followed six months later by the diversion of the KMCAS discharge from the Bay (NOAA, 2009).

Water quality in southern Kāneʻohe Bay was also impacted by increasing urban development during this same time period, resulting in increased runoff and entrainment of sediments and nutrients to southern Kāneʻohe Bay (Banner and Bailey, 1970; Banner, 1974), primarily from Kāneʻohe Stream and Keaʻahala Stream, and to a lesser degree, Kawa Stream. These inputs further contributed to the degradation of water quality in southern Kāneʻohe Bay.

Improving water quality conditions in southern Kāneʻohe Bay following sewage diversion has been well documented (Laws and Redalje, 1979, 1982; Smith, 1979, 1981; Laws, 1981). Since that time, additional studies have been conducted on factors influencing water quality in southern Kāneʻohe Bay. These include periodic monitoring by the Hawaii Department of Health (HDOH) from 1979 to 1997 at a station located in the central portion of southern Kāneʻohe Bay and a station located in the nearshore waters off Kāneʻohe Beach Park between 1991 and 1997 (EPA, 2009). The Coastal Intensive Site Network (CISNet) study generated bimonthly water quality data from 1998 to 2001, with one station located near the mouth of Kāneʻohe Stream and another station in the central portion of southern Kāneʻohe Bay. These stations were used to measure terrestrial inputs and influences on southern Kāneʻohe Bay water quality (SOEST, 2009). Other studies included sediment and nutrient inputs from streams (Hoover and Mackenzie, 2002) and storm events (DeCarlo et al., 2007; Ringuet et al., 2003) to southern Kāneʻohe Bay.

Methods

AECOS, Inc. technicians collected water quality samples from five stations in southern Kāneʻohe Bay, during three sampling events: September 23, October 15, and October 27, 2009. Figure 1 illustrates the station locations. Samples were collected in the surface waters at three nearshore stations (Stas. "Nuupia", "Kawa", and "Kaneohe"). For two stations (Stas. "B8000" and "B4500") located in the deeper waters of southern Kāneʻohe Bay, samples were collected from surface, mid-depth and bottom waters using a Van Dorn type sampler (Vertical Beta™ 4.2 Liter). Temperature, pH, and dissolved oxygen measurements were taken in situ from the sampler or directly from the surface layer. All collected samples were immediately placed in a cooler and chilled on ice for delivery to *AECOS*, Inc. laboratory in Kāneʻohe for analysis (*AECOS* Log Nos. 25628, 25683, and 25694). Table 1 lists the analytical methods and instrumentation used in this survey program.

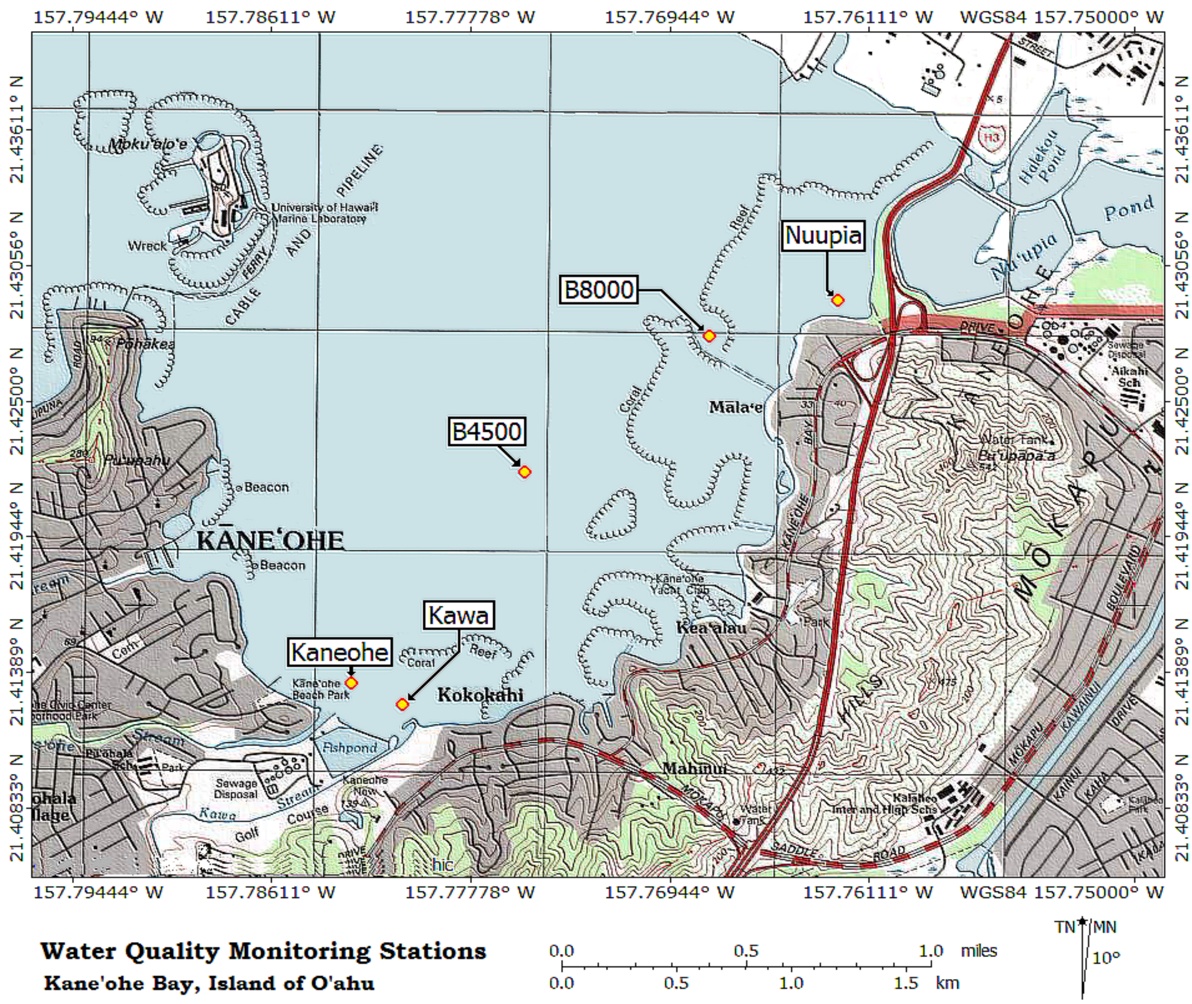

Figure 1. Locations of water quality sampling stations in southern Kāneʻohe Bay.

Results

A summary of the existing water quality conditions in southern Kāneʻohe Bay based upon the three sampling events is shown in Tables 2 and 3. Complete water quality data for each sampling event are given in Appendix A.

Mean water temperatures varied from a low of 27.3° C in the bottom waters at Sta. B8000 to a high of 29.1° C at Sta. Kaneohe, just offshore of Kāneʻohe Stream. Temperatures decreased with depth at Stas. B8000 and B4500. Mean salinity ranged from 20.40 PSU (brackish) at Sta. Kaneohe to a high of 35.16 PSU (typical ocean water value) in the bottom waters at Sta. 4500. Salinities increased with depth at Stas. B8000 and B4500.

Table 1. Analytical methods and instruments used for the analysis of water quality samples collected from southern Kāneʻohe Bay in September and October 2009.

Analysis	Method	Reference	Instrument
Ammonia	EPA 350 M	Grasshoff et al. (1986)	Technicon AutoAnalyzer II
Chlorophyll α	10200 H (M)	Standard Methods 20th Edition (1998)	Turner Fluorometer
Dissolved Oxygen	SM 4500-O G	Standard Methods 20th Edition (1998)	YSI Model 550A Dissolved Oxygen Meter
Nitrate + Nitrite	EPA 353.2 Rev 2.0	EPA (1993)	Technicon AutoAnalyzer II
pH	SM 4500 H+	Standard Methods 20th Edition (1998)	Hannah pocket pH meter
Salinity	SM 2520 B	Standard Methods 20th Edition (1998)	AGE Model 2100 bench salinometer
Temperature	thermister calibrated to NBS. Cert. thermometer SM 2550 B	Standard Methods 20th Edition (1998)	YSI Model 550A Dissolved Oxygen Meter
Total Nitrogen	persulfate digestion/EPA 353.2	Grasshoff et al (1986)/ EPA (1993)	Technicon AutoAnalyzer II
Total Phosphorus	persulfate digestion/EPA 365.1 Rev 2.0	Grasshoff et al. (1986)/EPA (1993)	Technicon AutoAnalyzer II
Total Suspended Solids	Method 2540 D	Standard Methods 20th Edition (1998)	Mettler H31 balance
Turbidity	EPA 180.1 Rev 2.0	EPA (1993)	Hach 2100N Turbidimeter

EPA. 1993. Methods for the Determination of Inorganic Substances in Environmental Samples. EPA 600/R-93/100.
Grasshoff, K., M. Ehrhardt, & K. Kremling (eds). 1986. Methods of Seawater Analysis (2nd ed). Verlag Chemie, GmbH, Weinheim.
Standard Methods. 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edition. 1998. (Greenberg, Clesceri, and Eaton, eds.). APHA, AWWA, & WEF. 1220 p.

Table 2. Summary of water quality for selected physicochemical parameters in southern Kāneʻohe Bay based on three sampling events.

Station	Arithmetic Means				Geometric Means	
	Temp. (°C)	Salinity (ppt)	DO Sat. (%)	pH	Turbidity (NTU)	TSS (mg/L)
Nuupia	27.4	33.10	98	7.74	2.85	6.8
B8000						
Surface	27.5	33.85	110	8.05	1.20	4.1
Mid-depth (14')	27.4	34.96	98	8.02	1.10	4.4
Bottom (25')	27.3	35.10	93	7.99	1.75	4.6
B4500						
Surface	28.2	33.97	111	8.08	0.98	3.8
Mid-depth (16.5')	27.7	34.95	108	8.05	0.95	4.0
Bottom (30')	27.4	35.16	91	8.04	5.09	9.7
Kawa	29.0	33.47	108	8.02	2.02	6.0
Kaneohe	29.1	20.40	110	7.98	1.94	5.9

Mean dissolved oxygen (DO) saturation levels ranged from 91% in the bottom waters at Sta. 4500 to a high of 111% in the surface waters also at Sta. B4500. Mean pH ranged from a low of 7.74 at Station Nuuipa to a high of 8.08 in the surface waters at Sta. B4500. DO saturation levels decreased with depth at both Stas. 8000 and 4500.

Geometric means were calculated for particulates (turbidity and total suspended solids [TSS]) and for nutrients for comparison with state water quality criteria (see below). Turbidity geometric means ranged from 0.95 NTU at mid-depth at Sta. B4500 to a high of 5.09 NTU in the bottom waters at Sta. B4500. Geometric mean values for TSS ranged from 3.8 mg/L in the surface waters at Sta. B4500 to a high of 9.7 mg/L in the bottom waters of Sta. B4500. TSS concentrations increased with depth at both Stas. 8000 and B4500, while turbidity did not.

Table 3. Summary of water quality results (geometric means) for nutrients and chlorophyll α in southern Kāneʻohe Bay, based on three sampling events

Station	NO_2+NO_3 (µg N/L)	Total N (µg N/L)	Total P (µg P/L)	Chl. α (µg/L)
B8000				
Surface	4	195	15	0.80
Mid-depth (14’)	5	193	14	1.10
Bottom (25’)	4	211	20	1.70
B4500	2	179	18	0.80
Mid-depth (16.5’)	1	198	19	0.83
Bottom (30’)	1	221	24	3.40
Kawa	14	251	21	1.43
Nuupia	8	237	24	1.06
Kaneohe	70	354	26	1.89

Geometric means for nitrate-nitrite ranged from 1 to 5 µg N/L at all depths at Stas. B4500 and B8000 to 70 µg N/L at Sta. Kaneohe near the mouth of Kāneʻohe Stream. Geometric means for total nitrogen (TN) ranged from 179 µg N/L, in the surface waters at Sta. B4500, to 354 µg N/L at Sta. Kaneohe. Total phosphorus means ranged from 14 µg P/L, in the mid-depth waters at Sta. B8000, to 26 µg P/L at Sta. Kaneohe. Samples for ammonia were collected and analyzed, but were consistently high for this parameter. In open waters of the Bay, ammonia should be around 5 µg N/L or less. Laboratory QA/QC was unable to attribute the problem to an analytical cause. Since these results are presently considered unreliable, the values have not been assessed further for this report.

Chlorophyll α means ranged from 0.80 µg/L, in the surface waters at Sta. 8000 and Sta. 4500 to a high of 3.40 µg/L, in the bottom waters at Station B4500. Chlorophyll α concentration increased with depth at Station B8000 and B4500.

State of Hawaiʻi water quality standards for embayments (HDOH, 2004; see Table 4) are divided into “wet” and “dry” criteria based upon fresh water inputs to the bay (see footnotes at bottom of Table 4). Because there are substantial stream and groundwater inputs to Kāneʻohe Bay, as evidenced by the reduced salinity levels at the shallow nearshore stations, the results of the present study are compared with appropriate "wet" criteria.

Table 4. State of Hawaiʻi water quality criteria for embayments (geometric mean values) for wet and dry embayments from HAR §11-54-06(a)(3).

Parameter	Geometric Mean value not to exceed this value	Value not to be exceeded more than 10% of the time	Value not to be exceeded more than 2% of the time
Total Nitrogen (µg N/l)	150.00	250.00	350.00
	200.00	*350.00*	*500.00*
Ammonia (µg N/l)	3.50	8.50	15.00
	6.00	*13.00*	*20.00*
Nitrate-Nitrite (µg N/l)	5.00	14.00	25.00
	8.00	*20.00*	*35.00*
Total Phosphorus (µg P/l)	20.00	40.00	60.00
	25.00	*50.00*	*75.00*
Chlorophyll α (µg/l)	0.50	1.50	3.00
	1.50	*4.50*	*8.50*
Turbidity (NTU)	0.40	1.00	1.50
	1.50	*3.00*	*5.00*

"dry" criteria apply when the average fresh water inflow from the land equals or exceeds one per cent of the embayment volume per day.

"wet" (*italicized*) criteria apply when the average fresh water inflow from the land equals or exceeds one per cent of the embayment volume per day.

Applicable to both "wet" and "dry" conditions:

- pH units shall not deviate more than 0.5 units from a value of 8.1.
- Dissolved oxygen shall not decrease below 75% of saturation.
- Temperature shall not vary more than 1 C^{o} from ambient conditions.
- Salinity shall not vary more than 10% from natural or seasonal changes.

Salinity and temperature during the three sampling events represent ambient conditions, to which future measurements might be compared and compliance with state criteria for these parameters determined. All dissolved oxygen (DO) saturation levels were greater than the minimum 75 percent specified by the DO saturation criterion (see Appendix A). pH values were within the range of 7.60 to 8.70, as specified by the criterion for this parameter.

Turbidity geometric means in the surface and mid-depth waters at Stas. B4500 and B8000 did meet the "wet" criterion, but the bottom waters of these two stations and Stas. Kawa, Nuupia, and Kaneohe did not meet the state criterion. There are no state water quality criteria for TSS in marine waters, but increases in TSS concentrations may occur from proposed project activities and the values reported herein serve as a baseline to gauge any project effects.

Nitrate-nitrite geometric means were in compliance with the geometric mean "wet" criterion at Stas. B4500 and B8000, but only at Sta. Nuupia of the three nearshore stations, suggesting Kawa and Kāneʻohe streams are sources of high nitrates. Total nitrogen geometric means exceeded the state geometric mean "wet" criterion at the nearshore stations and the bottom samples further out in the bay. Total phosphorus geometric means met the "wet" geometric mean criterion at all stations, except for Sta. Kaneohe which was very slightly above. The pattern for Chlorophyll α geometric means was very similar to that shown by the TN means.

Assessment

The water quality in southern Kāneʻohe Bay is influenced by fresh water inputs from both Kāneʻohe and Keaʻahala streams, and to a lesser degree Kawa Stream, especially during storm events. Fig. 2 shows nine significant storm events (with daily rainfall in excess of 1 inch [3.5 cm]) in Kāneʻohe over a two year period that influenced sediment and nutrient transport into southern Kāneʻohe Bay (SOEST, 2009).

Hoover and Mackenzie (2009) determined that storm events account for about 93% of suspended particulate matter entering Hawaiʻi coastal waters and about 85% of nutrient fluxes. Additionally, several studies have demonstrated that nitrogen and phosphorus moieties contained in Kāneʻohe Bay sediments have a direct effect on algal productivity (Larned and Stimson, 1996; Larned and Atkinson, 1997).

Excavation in the bottom of southern Kāneʻohe Bay would result in the resuspension of bottom sediments into the water column. This resuspension would directly affect turbidity and TSS concentrations in the water column. Based upon the studies cited above, it is likely that nitrogen and phosphorus moieties will be released from these sediments and could be utilized by benthic algae and phytoplankton productivity. Sediment suspension may affect changes to DO and pH, as well.

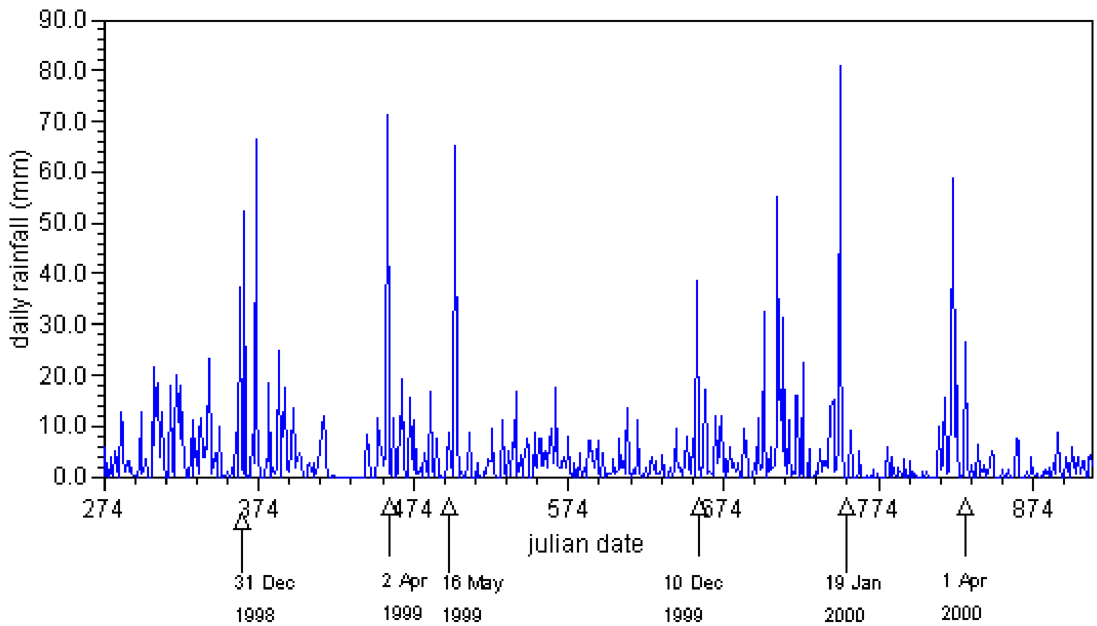

Figure 2. Daily rainfall as measured at the Luluku gauge in Kāneʻohe from mid 1998 through mid 2000 (SOEST, 2009).

Most of the length of the proposed pipeline will be drilled horizontally well below the surface of the bottom of the Bay, avoiding disturbance of the sediment. Only the dredging needed to excavate the connection points will disturb the bottom in a way having potential to impact on water quality. These locations (pipe connection points) will be surrounded by sheet pilings in order to isolate them from the waters of the Bay. Disturbance of the bottom sediment in these locations will be temporary. Silt curtains will be deployed to further limit the spread of any turbidity plumes generated by the construction. Changes in water quality caused by construction activities can be expected to be localized and temporary.

Spillage of pollutants such as diesel oil from boat and/or platform operations would degrade water quality in surface. The State of Hawaiʻi water quality standards (HDOH, 2004) mandated that:

> *"All waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including…floating debris, oil, grease…."*

Best management practices (BMPs) that should be employed during excavation include the deployment of containment devices/silt curtains and implementation of a water quality monitoring program to ensure that BMPs are containing particulates. A monitoring program should include sampling for turbidity, TSS, and nitrogen and phosphorus moieties both inside and outside the silt curtains and sheet piles used during excavation. The water quality data presented in this report represents general conditions, and preconstruction water quality sampling will likely be required.

Preventative BMPs for pollutant spills include proper storage of potential pollutants, appropriate training of personnel to prevent spills and implement clean-up operations in the event of a spill, and having proper clean-up gear onboard project boats and platforms at all times.

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Appendix A

Water Quality Data

Station	Time	Depth (ft.)	Temp (°C)	Salinity (ppt)	DO sat. (%)	pH
9/23/2009						
B8000-S	1132		28.5	34.05	95	7.96
B8000-M	1141	14	27.8	35.15	77	7.91
B8000-B	1150	25	27.5	35.23	88	7.90
B4500-S	1240		28.6	34.98	99	8.02
B4500-M	1248	16.5	27.9	35.30	94	8.03
B4500-B	1258	30	27.5	35.30	74	7.99
Nuupia	1048		28.0	34.49	84	7.55
Kawa	1322		29.9	33.52	115	8.07
Kaneohe	1345		30.1	33.94	118	8.06
10/15/2009						
B8000-S	0942		26.8	32.90	125	8.16
B8000-M	0953	14	27.2	34.88	111	8.08
B8000-B	1001	25	27.2	35.12	93	8.02
B4500-S	1105		27.9	33.04	121	8.14
B4500-M	1115	16.5	27.6	34.75	119	8.13
B4500-B	1124	30	27.6	35.19	95	8.05
Nuupia	1032		27.1	32.15	122	7.95
Kawa	1207		29.1	32.91	95	7.97
Kaneohe	1151		28.5	10.97	97	7.98
10/27/2009						
B8000-S	1043		27.2	34.59	110	8.04
B8000-M	1051	14	27.2	34.84	105	8.07
B8000-B	1101	25	27.1	34.96	98	8.05
B4500-S	0113		28.2	33.90	112	8.08
B4500-M	1136	16.5	27.7	34.80	111	8.00
B4500-B	1141	30	27.2	34.98	104	8.07
Nuupia	1028		27.0	32.66	88	7.71
Kawa	1201		28.1	33.98	114	8.03
Kaneohe	1215		28.6	16.30	114	7.91

Station	Turbidity (NTU)	TSS (mg/L)	Ammonia (μgN/L)	NO2+NO3 (μgN/L)	TN (μgN/L)	TP (μgP/L)	Chl. α (μg/L)
9/23/2009							
B8000-S	1.26	4.5		5	216	<20	0.73
B8000-M	0.98	5.7		6	247	<20	1.07
B8000-B	0.88	2.7		2	216	<20	1.08
B4500-S	0.77	3.6		2	202	<20	0.64
B4500-M	1.10	4.3		2	257	<20	0.76
B4500-B	8.42	10.0		1	277	<20	3.91
Nuupia	3.56	9.0		7	279	<20	1.93
Kawa	2.12	7.5		11	267	<20	1.36
Kaneohe	1.59	5.9		8	248	<20	1.33
10/15/2009							
B8000-S	1.34	4.4	*76*	11	205	15	0.53
B8000-M	1.32	3.8	*69*	8	174	11	0.71
B8000-B	4.32	8.6	*88*	12	227	17	1.83
B4500-S	1.15	5.1	*67*	1	166	24	0.64
B4500-M	0.66	3.6	*69*	1	181	25	0.45
B4500-B	4.64	9.0	*68*	1	206	31	3.84
Nuupia	3.30	6.0	*74*	4	214	35	0.63
Kawa	1.51	5.3	*92*	13	265	32	1.59
Kaneohe	2.45	8.2	*124*	156	423	31	3.14
10/27/2009							
B8000-S	1.02	3.6	*65*	1	167	14	1.33
B8000-M	1.04	4.0	*67*	2	168	16	1.73
B8000-B	1.42	4.3	*68*	3	192	29	2.47
B4500-S	1.05	3.0	*66*	2	171	17	1.23
B4500-M	1.18	4.1	*68*	1	168	18	1.65
B4500-B	3.37	10.2	*67*	1	189	31	2.61
Nuupia	1.98	5.7	*77*	16	222	26	0.98
Kawa	2.56	5.5	*82*	21	223	20	1.35
Kaneohe	1.87	4.2	*100*	276	421	37	1.62

Appendix C

Botanical Survey of Terrestrial Sites for a Subterranean Sewer Main Project in Kaneohe, Oahu

AECOS, Inc.

August 2010

Botanical survey of terrestrial sites for a subterranean sewer main project in Kāneʻohe, Oʻahu

Prepared for Austin Tsutsumi & Associates, Inc.[1]

August 26, 2010 *AECOS* No. 1215D

Eric Guinther
AECOS Inc.
45-939 Kamehameha Highway, Suite 104
Kāneʻohe, Hawai`i 96744
Phone: (808) 234-7770 Fax: (808) 234-7775 Email: guinther@aecos.com

Introduction

A proposed sewer force main connecting the Kāneʻohe Wastewater Treatment Plant (WWTP) with the ʻAikahi WWTP on windward Oʻahu is in early planning stages. A subterranean pipeline beneath Kāneʻohe Bay (Fig. 1) is being considered as an alternative to a land-based route for the new pipeline to supplement or replace the existing pipeline linking the Kāneʻohe and Kailua plants. Microtunneling and pulling (jacking) the pipe through the tunnel will require setups on the land at either end. In addition, base yards are anticipated where the pipe sections are connected prior to deployment under the Bay. Two alternative routes crossing the south part of Kāneʻohe Bay (Fig. 1) are currently under consideration, however, these come ashore at the Kailua[2] (ʻAikahi) end at the same point, and are close together at the Kāneʻohe end.

Potential impact areas at the southern or Kāneʻohe end extend from the mouth of Kāneʻohe Stream to the vicinity of the Kokokahi YWCA. Potential impact areas at the northern or ʻAikahi end would be inland from the in the vicinity of the H-3/Kāneʻohe Bay Drive exchange.

[1] This report was prepared for Austin Tsutsumi & Associates, Inc., Honolulu; to be used as needed for planning purposes. This report may become part of the public record for permitting or due diligence purposes.

[2] Although we describe this area as the Kailua end of the project, in fact no part of the project is in Kailua since ʻAikahi, like Mōkapu, is technically part of Kāneʻohe, although served by the Kailua Post Office.

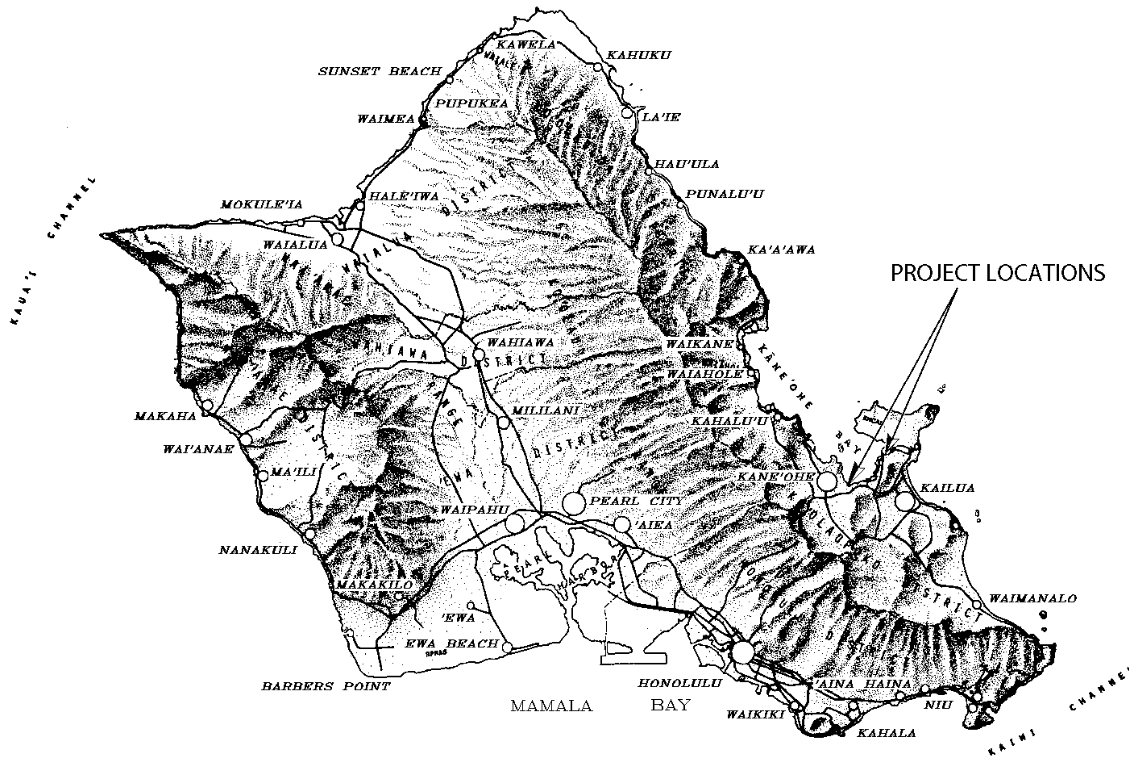

Figure 1. Survey locations on the Island of Oʻahu.

Methods

On February 10, 2010, a pedestrian botanical survey was made by *AECOS* biologist, Eric Guinther, of areas potentially impacted by the land sites at the Kāneʻohe end (Fig. 2) of the proposed subterranean sewer force main. The survey area included Waikalua Loko (fishpond), the Kaneohe Pump Station (former WWTP), and the Bay View Golf Course. The survey consisted of walking the subject areas (at Bay View Golf Course, a cart was used to access areas on the course) using a handheld GPS unit (Trimble GeoXT) to ensure complete coverage of the properties in the areas shown in Fig 2. All plant species encountered were noted. A return visit was made on August 20, 2010 to enhance assessment of wetland boundaries in proposed pipe set-up areas potentially impinging on Kāwā Stream and a wetland on Bay View Golf Course property.

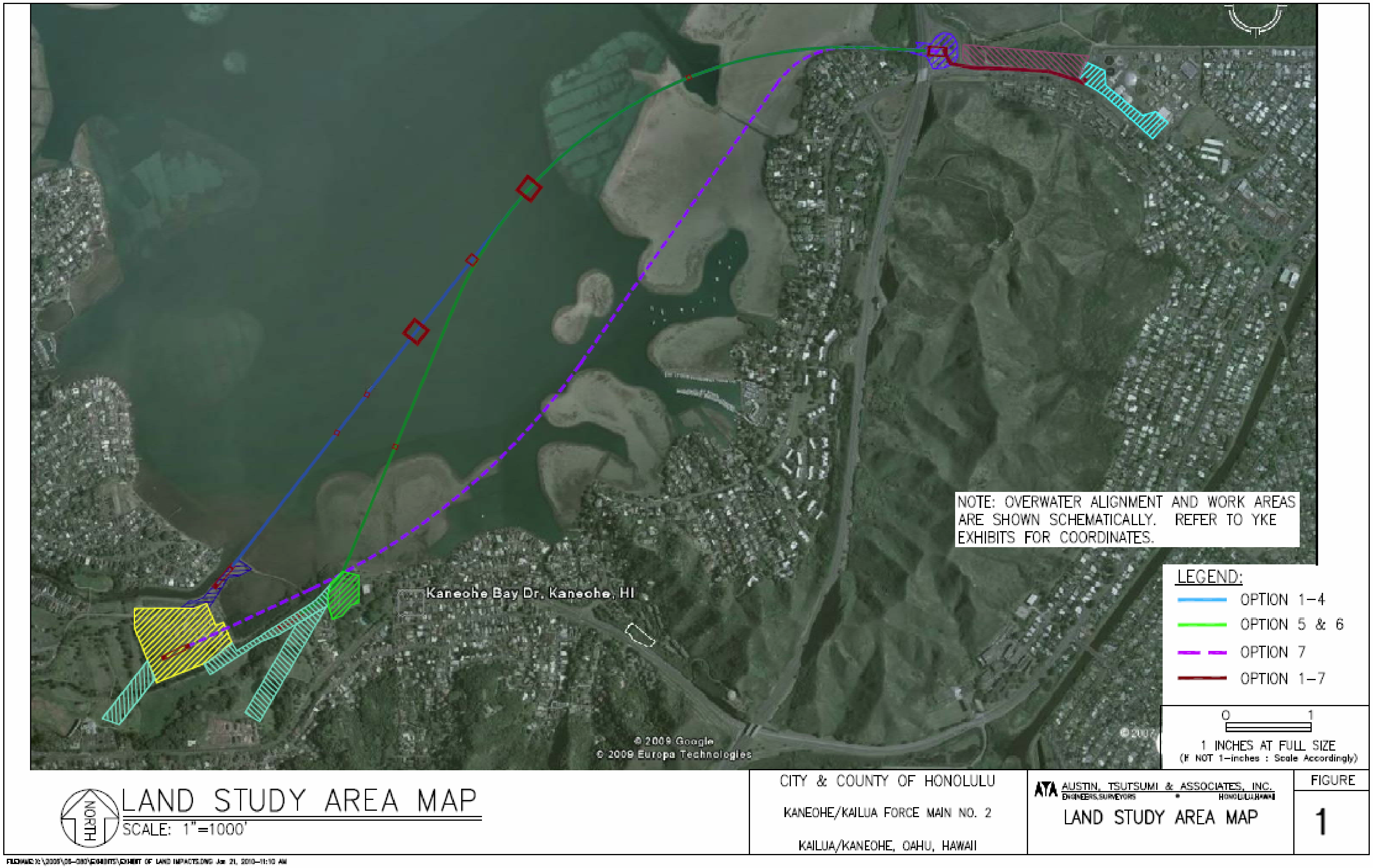

Figure 2. Overall project scope with various alternatives and potential on land work areas.

Several past botanical surveys have been conducted in the project areas, including: Linney and Char (1989) and AECOS (2006, 2008). The species listed in these reports have been incorporated into Table 1 (see footnotes).

Names of ferns and fern allies follow Palmer (2003). Flowering plant names follow *Manual of the Flowering Plants of Hawaiʻi* (Wagner et al. and Wagner and Herbst, 1990, 1999). Ornamental plant names follow *A Tropical Garden Flora: Plants Cultivated in the Hawaiian Islands and Other Tropical Places* (Staples and Herbst, 2005). Hawaiian and scientific names of plants are italicized in the text.

Results

The results of the surveys are expressed as a description of the vegetation and a listing of plant species encountered (Table 1). The vegetation in all areas is typical of disturbed or landscaped environments, with the exception of the mangal (*Rhizophora mangle* mangrove forest) present along the shore, in Waikalua Loko fishpond, and up into lower Kawa Stream. Inland from the mangal is typically a sparse to moderate growth of *milo* (*Thespesia populnea*). Some not recently disturbed areas are covered by grasses and scattered shrubs. Landscaped areas predominate at the Kāneʻohe Pump Station, the Bay View Golf Course, the YWCA, and the H-3 interchange. Landscaping involves both regular mowing of lawn grasses and maintenance of plantings of trees and shrubs, mostly or typically ornamental species. Wetlands occur in two areas: along the shore and estuarine areas (mangal is a wetland type), and a freshwater wetland on undeveloped land at the Bay View Golf Course (see below).

Although we prefer to provide a qualitative sense of abundance of each species as part of the list of species (flora; Table 1), the survey covered such a diversity of environments—from along the Kāneʻohe Bay shoreline, to riparian areas of Kāneʻohe and Kāwā streams, to ruderal sites associated with roads and construction areas, to highly manicured grounds of the golf course—that describing abundance proved impossible without reference to the many localized environments.

The survey by *AECOS* (2008) on the Bay View Golf Course encompassed the channel of Kawa Stream and immediate surrounding ground, from just downstream of Kāneʻohe Bay Drive to a point not far downstream of the lowest cart path over the stream. The present survey started near the same cart path and extended downstream to the mouth and on the golf course west as far as Kāneʻohe Stream and east as far as Kāneʻohe Bay Drive, although some undeveloped and forested areas not proposed impacts by the project were not surveyed.

Table 1. Checklist of plants found in potential terrestrial project areas, Kaneohe Force Main Project

Family Species	Common name	STATUS	TYPE	NOTES
PTERIDOPHYTES ~ FERNS & FERN ALLIES				
POLYPODIACEAE				
Phlebodium aureum (L.) J. Sm.	rabbit's foot fern	Nat	H	<5>
Phymatosorus grossus (Langsd. & Fisch.) Brownlie	*lauaʻe*	Nat	H	<2,4,5>
THELYPTERIDACEAE				
Christella parasitica (L.) H. Lév.	wood fern	Nat	H	<2,5>
FLOWERING PLANTS				
DICOTYLEDONS				
ACANTHACEAE				
Asystasia gangetica (L.) T. Anderson	Chinese violet	Nat	H	<4,5>
Justicia betonica L.	white shrimp plant	Nat	H	
Thunbergia fragrans R oxb.	sweet clock vine	Nat	H	
AIZOACEAE				
Sesuvium portulacastrum (L.) L.	*ʻākulikuli*	**Ind**	H	<4>
Trianthema portulacastrum L.	---	Nat	H	
AMARANTHACEAE				
Alternanthera sessilis (L.) R.Br. Ex DC	sessile joyseed	Nat	H	<2,5>
Amaranthus spinosus L.	spiny amarnth	Nat	H	
Amaranthus viridis L.	slender amaranth	Nat	H	
ANACARDIACEAE				
Mangifera indica L.	mango	Nat	T	
Schinus terebinthifolius Raddi	Christmas berry	Nat	T	<4>
APIACEAE				
Centella asiatica (L.) Urb.	Asiatic pennywort	Nat	H	
Ciclospermum leptophyllum (Pers.) Sprague	fir-leaved celery	Nat	H	
APOCYNACEAE				
Allamanda cathartica L.	allamanda	Orn		
Catharanthus roseus (L.) G. Don	periwinkle	Nat	H	
Plumeria obtusa L.	Singapore plumeria	Orn	T	
ARALIACEAE				
Schefflera actinophyla (Endl.) Harms	octopus tree	Nat	T	<5>
ASTERACEAE (COMPOSITAE)				
Ageratum conyzoides L.	*maile hohono*	Nat	H	

Table 1 (continued).

Family Species	Common name	STATUS	TYPE	NOTES
ASTERACEAE (continued)				
Ageratum houstonianum Mill.	*bluemink*	Nat	H	<2,5>
Bidens alba (L.) DC	beggartick	Nat	H	
Bidens pilosa L.	beggartick	Nat	H	<4>
Calyptocarpus vialis Less.	---	Nat	H	<1>
Conyza bonariensis (L.) Cronq.	hairy horseweed	Nat	H	
Dyssodia tenuiloba (Cand.) Robinson	---	Nat	H	
Emilia fosbergii Nicolson	Flora's paintbrush	Nat	H	<5>
Lactuca serriola L.	prickly lettuce	Nat	H	
Pluchea indica (L.) Less.	Indian fleabane	Nat	S	<4>
Pluchea carolinensis	sourbush	Nat	S	
Sigesbeckia orientalis L.	small yellow crownbeard	Nat	H	<2,5>
Sonchus oleraceus L.	*pualele*	Nat	H	<5>
Spagneticola trilobata (L.)	wedelia	Nat	H	<4,5>
Synedrella nodiflora (L.) Gaertn.	nodeweed	Nat	H	
Taraxacum officinale W.W. Weber ex Wigg.	common dandelion	Nat	H	<2,5>
Tridax procumbans L.	coat buttons	Nat	H	<4>
Xanthium strumarium var. *canadense* (Mill.) Torr. & A. Gray	cocklebur, *kikania*	Nat	H	<2,5>
Youngia japonica (L.) DC	Oriental hawksbeard	Nat	H	
BATACEAE				
Batis maritima L.	pickleweed	Nat	S	<4>
BIGNONIACEAE				
Spathodea campanulata P. Beauv.	African tulip tree	Nat	T	
Tabebuia aurea (Silva Manso) S. Moore	silver trumpet	Orn	T	
Tabebuia heterophylla (A.P. de Candolle) Britton	pink tecoma	Orn	T	
BORAGINACEAE				
Heliotropium curassavivum L.	*kīpūkai*	**Ind**	H	<6>
Heliotropium procumbens Mill.	---	Nat	H	
BRASSICACEAE				
Brassica campestris L.	field mustard	Nat	H	
Cardamine flexuosa With.	woodland bittercress	Nat	H	<2,5>
Coronopus didymus (L.) Sm.	swinecress	Nat	H	
CARICACEAE				
Carica papaya L.	papaya	Nat	H	<2,5>

Table 1 (continued).

Family Species	Common name	STATUS	TYPE	NOTES
CASUARINACEAE				
Casuarina equisetifolia L.	common ironwood	Nat	T	<2,4>
CLUSIACEAE				
Clusia rosea Jacq.	autograph tree	Nat	T	
COMBRETACEAE				
Conocarpus erectus L.	buttonwood	Nat	T	<3,4>
Terminalia catappa L.	tropical almond	Nat	T	<2,4>
CONVOLVULACEAE				
Ipomoea alba L.	moonflower	Nat	V	<2, 5>
Ipomoea obscura (L.) Ker-Gawl.	---	Nat	V	
Ipomoea triloba L.	little bell	Nat	V	
Merremia tuberose (L.) Rendle	wood rose	Nat	V	
CUCURBITACEAE				
Coccinia grandis (L.) Voigt	scarlet-fruited gourd	Nat	H	
EUPHORBIACEAE				
Aclypha wilkesiana Müller Arg.	beefsteak plant	Orn	S	
Aleurites moluccana (L.) Wild.	*kukui*	**Pol**	T	
Chamaesyce hirta (L.) Millsp.	garden spurge	Nat	H	
Chamaesyce hypericifolia (L.) Millsp.	graceful spurge	Nat	H	
Codiaeum variegatum (L.) Blume	croton	Orn	S	
Phyllanthus debilis Klein ex Willd.	niuri	Nat	H	
Ricinus communis L.	castor bean	Nat	S	
FABACEAE				
Acacia confusa Merr.	Formosan *koa*	Nat	T	
Acacia farnesiana (L.) Willd.	*klu*	Nat	S	<2,4>
Albizia lebbeck (L.) Benth.		Nat	T	
Bauhania cf. *galpinii* N.E. Brown	nasturtium bauhania	Orn	T	<2,4>
Canavalia cathartica Thouars	*maunaloa*	Nat	V	
Canavalia sericea A. Gray	silky jackbean	Nat	V	<3>
Cassia x *nealiae* Irwin & Balwin.	rainbow shower	Orn	T	<6>
Centrosema molle Mart. ex Benth.	---	Orn	V	
Chamaecrista nictitans (L.) Moench	partridge pea	Nat	H	
Crotalaria incana L.	fuzzy rattlepod	Nat	H	
Desmanthus pernambucanus (L.) Thellung	virgate mimosa	Nat	H	<4>
Desmodium tortuosum (Sw.) DC	Florida beggarweed	Nat	H	
Enterolobium cyclocarpum (N. Jacq.) Gris.	earpod	Orn	T	

Table 1 (continued).

Family Species	Common name	STATUS	TYPE	NOTES
FABACEAE (continued)				
Falcataria moluccana (Miq.) Barneby & Grimes	albizia	Nat	T	
Indigofera hendycaphyla	creeping indigo	Nat	H	<5>
Indigofera suffruticosa Mill.	indigo	Nat	S	
Leucaena leucocephala (Lam.) deWit	*koa haole*	Nat	S, T	<4,5>
Macroptilium lathyroides (L.) Urb.	wild bean	Nat	H	
Medicago sp.	bur clover	Nat	H	
Melilotus indica (L.) All.	yellow sweet clover	Nat	H	
Mimosa pudica var. *unijuga* (Duchass. & Walp.) Griseb.	sensitive plant	Nat	H	<5>
Neonotonia wightii (Wight & Arnott) Lackey	glycine vine	Nat	H	
Prosopis palliada (Humb. & Bonpl. Ex Willd.) Kunth	*kiawe*	Nat	T	<2,4>
Samanea saman (N. Jacq.) Merr.	monkeypod	Nat	T	<4>
Senna surattensis (Burm. f.) H. S. Irwin & Barneby	scrambled egg plant	Orn	S	<2,5>
GOODENIACEAE				
Scaevola sericea Vahl.	*naupaka kahakai*	**Ind**	S	
LAMIACEAE				
Hyptis pectinata (L.) Poit.	comb hyptis	Nat	H	
MALVACEAE				
Abutilon grandifolium (Willd.) Sweet	hairy abutilon	Nat	S	
Hibiscus rosa-sinensis L.	Chinese hibiscus	Orn	S	
Hibiscus tiliaceus L.	*hau*	**Ind**	T,S	<5>
Malva parviflora L.	cheeseweed	Nat	H	
Malvastrum americanum (L.) Torr.	false mallow	Nat	H	
Sida spinosa L.	prickly sida	Nat	H	
Thespesia populnea (L.) Sol. ex Corrêa	*milo*	**Ind**	T	
MELASTOMATACEAE				
Clidemia hirta (L.) D. Don var. hirta	Koster's curse	Nat	H	
MORACEAE				
Ficus microcarpa L.	Chinese banyan	Nat	T	<5>
MORINGACEAE				
Moringa oleifera Lam.	horseradish tree	Orn	T	

Table 1 (continued).

Family Species	Common name	STATUS	TYPE	NOTES
MYRTACEAE				
Callistemon viminalis (J. Gaertn.) Loudon	weeping bottlebrush	Orn	T	
Melaleuca quinquenervia (Cav.) S.T. Blake	paperbark	Nat	T	
Psidium cattleianum Sabine	strawberry guava	Nat	S	
Psidium guajava L.	common guava	Nat	T	
Syzigium cumini (L.) Skeels	Java plum	Nat	T	<5>
NYCTAGINACEAE				
Boerhavia coccinea Mill.	false *alena*	Nat	H	<2,4>
Bougainvillea spectabilis Wild.	bougainvillea	Orn	S	
OXALIDACEAE				
Oxalis corniculata L.	yellow wood sorrel	**Ind**	H	
Oxalis debilis var. *corymbosa* (A.P. de Candolle) Lour.	pink wood sorrel	Orn	H	
PLANTAGINACEAE				
Plantago major L.	common plantain	Nat	H	<5>
POLYGONACEAE				
Coccoloba univera (L.) L.	sea grape	Nat	T	<2,4>
PRIMULACEAE				
Anagallis arvensis L.	scarlet pimpernel	Nat	H	
RHIZOPHORACEAE				
Rhizophora mangle L.	red mangrove	Nat	T	<4, 5>
RUBIACEAE				
Morinda citrifolia L.	*noni*	Pol	S/T	
Padaeria foetida L.	*maile pilau*	Nat	V	
Spermacoce assurgens Ruiz & Pav.	buttonweed	Nat	H	
SAPINDACEAE				
Filicium decipiens (Wight & Arnott) Thwaites	fern tree	Nat	T	
SOLANACEAE				
Solanum americanum Mill.	pōpolo	**Ind**	H	
Solanum lycopersicum var. *cerasiforme* (Dunal) Spooner	cherry tomato	Nat	H	
Solanum mauritianum Scop.	*pua nānā honua*	Nat	H	
Solanum torvum Sw.	---	Nat	H	
STERCULIACEAE				
Waltheria indica L.	*ʻuhaloa*	**Ind**	H	

Table 1 (continued).

Family Species	Common name	STATUS	TYPE	NOTES
ULMACEAE				
Trema orientalis (L.) Blume	gunpowder tree	Nat	T	
VERBENACEAE				
Citharexylum caudatum L.	fiddlewood	Nat	S	
Stachytarpheta australis Moldenke	---	Nat	H	<2,4>
Stachtarpheta dichotoma (Ruiz & Pav.) Vahl	*owi*	Nat	H	
MONOCOTYLEDONES				
AGAVACEAE				
Cordyline fruticosa (L.) A. Chev.	ti, *ki*	**Pol**	S	
Dracaena fragrans (L.) Ker Gawl.	fragrant dracaena	Orn	H	
ARACEAE				
Dieffenbachia maculata (Loddiges) G. Don	dumb cane	Orn	H	
Epipremnum pinnatum 'Aureum' G.S. Bunting	pothos	Nat	V	
Syngonium cf. *podophyllum* Schott	nephthytis	Nat	V	
Xanthosoma robustum Schott	ʻape	Nat	H	<5>
ARECACEAE				
Archontophoenix alexandrae (F. Mueller) H. Wendl.	Alexandra palm	Nat	T	<1>
Cocos nucifera L.	coconut, *niu*	**Pol**	T	<4, 5>
Dypsis lutescens (H. Wendl.) Beentje & Dransfield	golden-fruited palm	Orn	T	
Phoenix hybrid	Phoenix palm	Nat	T	
Pritchardia thurstonii F. Mueller & Drude	Fiji fan palm	Orn	T	
Wodyetia bifurcata Irwine	foxtail palm	Orn	T	
CANNACEAE				
Canna indica L.	canna, Indian-shot	Orn	H	<6>
COMMELINACEAE				
Commelina diffusa N.L. Burm.	day flower	Nat	H	<5>
CYPERACEAE				
Cyperus gracilis R. Br.	McCoy grass	Nat	H	<5>
Cyperus involucratus Rottb.	umbrella sedge	Nat	H	<5>
Cyperus polystachyos Rottb.	---	**Ind**	H	
Cyperus rotundus L.	nut grass	Nat	H	
Fimbristylis dichotoma (L.) Vahl	---	**Ind**	H	<2,4>

Table 1 (continued).

Family Species	Common name	STATUS	TYPE	NOTES
CYPERACEAE (continued)				
Kyllinga nemoralis (J.R. Forster & G. Forster) Dandy ex Hutchinson & Dalziel	*kiliʻoʻopu*	Nat	H	
MUSACEAE				
Musa cultivar	banana	Orn	H	<5>
PANDANACEAE				
Pandanus tectorius Z		**Ind**	T	
POACEAE (GRAMINEAE)				
Andropogon virginicus L.	broomsedge	Nat		
Axonopus compressus (Swartz) P. Beau.	brd-lvd carpetgrass	Nat	H	<1,5>
Bothriochloa pertusa (L.) Camus	pitted beardgrass	Nat	H	<5>
Cenchrus echinatus L.	commom sandbur	Nat	H	<5>
Chloris barbata (L.) Sw.	swollen fingergrass	Nat	H	<4>
Chloris virgata Sw.	feather fingergrass	Nat	H	
Coix lacryma-jobi L.	Job's tears	Nat	H	<5>
Cynodon dactylon (L.) Pers.	Bermuda grass	Nat	H	<4,5>
Cynodon hybrid	Tifdwarf	Orn	H	<6>
Digitaria ciliaris (Retz.) Koeler	Henry's crabgrass	Nat	H	<1>
Digitaria insularis (L.) Mez ex Ekman	sourgrass	Nat	H	
Digiteria sp.	v. long racemes	Nat	H	
Echinochloa colona (L.) Link	jungle-rice	Nat	H	
Eleusine indica (L.) Gaertn.	wiregrass	Nat	H	<5>
Eragrostis pectinacea (Michx.) Nees	Carolina lovegrass	Nat	H	<5>
Leptochloa uninervia (K. Presl.) Hitchc. & Chase	sprangletop	Nat	H	
Melinus repens	Natal redtop	Nat	H	
Paspalum conjugatum Bergius	Hilo grass	Nat	H	<1,5>
Paspalum fimbriatum Kunth	Panama paspalum	Nat	H	
Paspalum scrobiculatum L.	ricegrass	**Ind**	H	<2,5>
Paspalum urvillei Steud.	Vasey grass	Nat	H	<2,5>
Pennisetum purpureum Schumach.	elephant grass	Nat	H	<5>
Setaria verticillata (L.) P. Beauv.	bristly foxtail	Nat	H	
*Sorghum halepense (*L.) Pers.	Johnson grass	Nat	H	
Sporobolus cf. *indicus* (L.) R. Br.	dropseed	Nat	H	
Sporobolis virginicus		Ind	H	
Urochloa maxima (Jacq.) Webster	Guinea grass	Nat	H	<4,5>
Urochloa mutica (Forssk.) Nguyen	California grass	Nat	H	<5>
STRELITZIACEAE				
Ravenala madagascariensis Sonnerat	traveler's tree	Orn	T	

Table 1 (continued).

Legend to Table 1

Status = distributional status

end. =	endemic; native to Hawaii and found naturally nowhere else.
ind. =	indigenous; native to Hawaii, but not unique to the Hawaiian Islands.
nat. =	naturalized, exotic, plant introduced to the Hawaiian Islands since the arrival of Cook Expedition in 1778, and well-established outside of cultivation.
orn. =	exotic, ornamental or cultivated; plant not naturalized (not well-established outside of cultivation).
pol. =	Polynesian introduction before 1778.

Abundance = occurrence ratings for plants in survey area.

R – Rare -	only one, two, or three plants seen.
U - Uncommon -	several to a dozen plants observed.
O - Occasional -	found regularly around the site.
C - Common -	considered an important part of the vegetation and observed numerous times.
A - Abundant -	found in large numbers; may be locally dominant.
AA - Abundant -	abundant and dominant in some areas surveyed, defining vegetation in those areas.

Notes:

<1> a naturalized species utilized as an ornamental.
<2> From referenced reports only; not recorded in this (2010) survey.
<3> plant lacking seasonal flowers or fruit; identification uncertain.
<4> Also recorded in AECOS (2006) between shore and H-3 freeway
<5> Also recorded in AECOS (2008) near and along Kawa Stream at the Bay View Golf Course.

The following description is of the mangrove forest along the H-3 Freeway shoreline in the general area proposed for the ʻAikahi end of the project. The tunneling method proposed would pass deep below the shoreline at this point, so no disturbance of the shore vegetation is anticipated in this location. The vegetation at and behind the shore is described as follows (AECOS, 2006, p. 26-28):

> A narrow belt of red mangrove lines the shore of the H-3 causeway from the MCBH-KB Mokapu Central Drainage Channel (MCDC) outlet near the base main gate to the southern culvert (Culvert No. 5) for Nuʻupia ʻEkahi pond. In the middle of this segment, mangroves extend to the very edge of the reef flat (actually to the dredged face of the reef) with the prop roots adjacent to coral colonies... Further south, the mangrove belt is widely separated from coral bottom areas. South of Culvert No. 5, the mangrove expands into a mangal—a mangrove forest—that continues the length of the causeway shore to an area of residential lots along Kāneʻohe Bay Drive … The mangal ends in the crux formed where the causeway meets the original shore at ʻAikahi. Only scattered occurrences of mangrove trees occur along the shore of Kāneʻohe Bay to the west and south of the causeway because of a narrow dredged boat channel just off the shore and presumably the efforts by property owners to maintain this channel and private inlets and docks free for navigation. …The …area is the largest or second largest concentration of mangrove plants in south Kāneʻohe Bay,

> the other of comparable size being that associated with Waikalua [Loko] Fishpond and Kāwā Stream at Kokokahi some 1.7 mi (2.7 km) distant.
>
> The mangal off the southern end of H-3 causeway has a closed-canopy of mature trees and a dense understory of prop roots and young trees. There is one large (100 ft or 30 m diameter) mangrove islet off the Nuʻupia ʻEkahi culvert channel; the islet is currently being used as a "campsite." Several smaller mangrove islets and numerous isolated young trees growing on the reef flat seaward of the forest indicate that the mangrove forest is expanding seaward…

AECOS (2006) listing of plant species extended from the shoreline along the H-3 causeway up to and including part of the H-3/Kāneʻohe Bay Drive Interchange.

Jurisdictional Waters

Jurisdictional waters or Waters of the U.S. are waters subject to the tide, streams, and wetlands that come under the jurisdictional authority of the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (USACE). Kāneʻohe Bay is a jurisdictional water; so are Kāneʻohe and Kāwā streams, Waikalua Loko and other nearby fishponds, and the wetland on the Bay View Golf Course directly south of Kāwā Stream (see Fig. 3). The wetland boundary, in this latter case, appears to have originally come from Elliott and Hall (1977) as presented in Linney and Char (1998). In general, the old boundary as depicted appears fairly accurate as compared with the present outline of this wetland. No other areas in the immediate vicinity of the project were identified in our survey as being Waters of the U.S.

Conclusions

No plant species listed as endangered, threatened, or currently proposed for listing under either federal or state endangered species statutes are known from the project site (USFWS, 2005a, 2005b, 2009), nor are any expected given the highly disturbed nature of the area. No listed species were reported from the same areas in earlier botanical surveys (Linney & Char, 1989; AECOS, 2006, 2008).

From a floristic perspective there exists no reasons or constraints that would suggest areas proposed for work on the land related to a subterranean sewer force main beneath Kāneʻohe Bay would be detrimental to botanical resources. The proximity of jurisdictional waters to areas under consideration for on land operations will require consideration of how these operations might impinge on

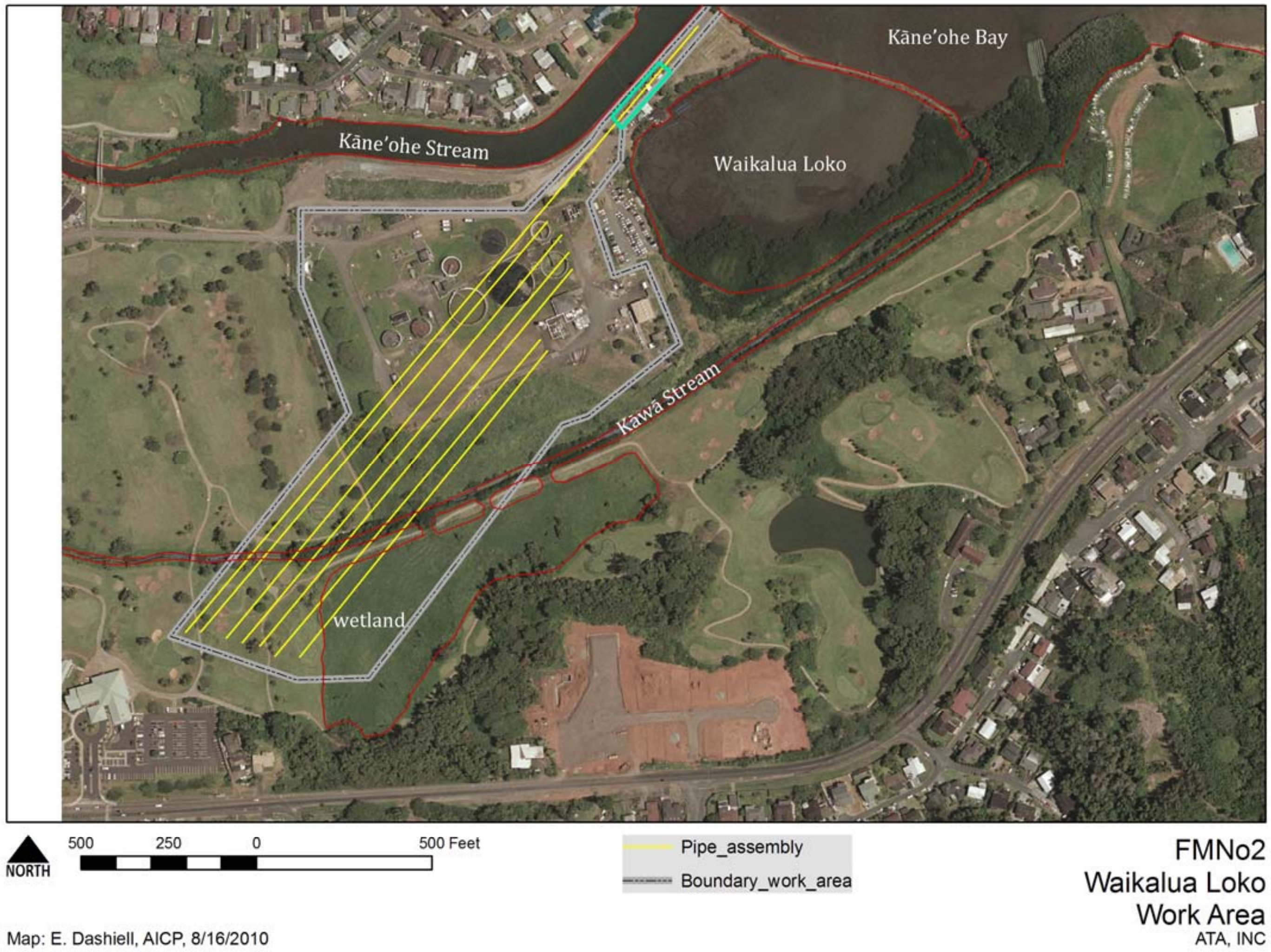

Figure 3. Work area map at the Kaneohe WWTP end showing wetlands and other jurisdictional waters bounded in red (boundaries are approximate)

jurisdictional waters. A permit for placing fill (including structures) could be needed, and a delineation of the jurisdictional boundary is typically a first step in moving towards an Army permit application under Section 404 of the Clean Water Act.

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Appendix D

Avifaunal Surveys and Assessment of Impacts to All Listed Species for the Kaneohe – Kailua Sewer Main Upgrade Project Alternatives

AECOS, Inc.

December 2010

Avifaunal surveys and assessment of impacts to all listed species for the Kāneʻohe-Kailua sewer main upgrade project alternatives

December 10, 2010 *AECOS* No. 1215E

Chad Linebaugh
AECOS, Inc.
45-939 Kamehameha Hwy, Suite 104
Kāne'ohe, Hawai'i 96744
Phone: (808) 234-7770 Fax: (808) 234-7775 Email: aecos@aecos.com

Introduction

Two subterranean pipelines routes have been proposed as alternatives to upgrade the existing 42-in (107-cm) sewage force main linking the Kāneʻohe Waste Water PreTreatment Facility (WWPTF) and Kailua (ʻAikahi) Regional Waste Water Treatment Plant (RWWTP), both on windward Oʻahu. One alternative proposes a 36-in (91-cm) force main extending 10,845 ft (3305 m) northeast from the Kāneʻohe facility to the Kailua plant (both herein referred to as WWTP) beneath the bottom of Kāneʻohe Bay. A second alternative proposes a gravity tunnel connecting the two sites beneath Oneawa Hills (Fig. 1). Studies on marine (water quality and biota) and terrestrial botanical resources have been completed for the project (*AECOS*, 2009, 2010a, 2010b, 2010c). *AECOS*, Inc has been contracted by Wilson Okamoto Corp., to survey avifaunal resources and assess possible impacts to birds and any threatened or endangered species potentially found in proposed work areas. This report details the results of the additional field surveys and a literature search of related information.

Currently, no in-water construction activities are anticipated for the under Kaneʻohe Bay force main alternative. However, contingency planning includes the possibility of an emergency work area being utilized within the bay, should an emergency arise. The emergency work area, isolated from surrounding waters by sheet piles, would allow for an access shaft to recover or repair subterranean drilling equipment used for the project. Similarly, the underground gravity tunnel alternative would require an access shaft to be located near the Board of Water Supply (BWS) water tank on Mōkapu (Saddle) Road, herein referred to as the Kapaʻa Access Shaft (Fig. 1).

Figure 1. Southern Kāneʻohe Bay vicinity, showing existing sewer force main (yellow) and proposed routes of two project alternatives (red and blue).

Methods

Avifaunal Surveys

Six avian count stations located near project work areas were surveyed for ten minutes each to identify species present in or transiting through the survey area. Auditory patterns or calls were not counted as individuals. Rather, identification and avian species counts were based on visual observations of physical features and flight patterns. Locations of count stations include: 1) near the entry gate, Kāneʻohe WWTP, 2) the east end Kāneʻohe WWTP, 3) the center of the western shore of Waikalua Fishpond, 4) the pipe entry work area along Kāneʻohe Stream, 5) the H-3 roundabout/Kailua work area, and 6) the proposed Kapaʻa access shaft location off Mōkapu (Saddle) Rd. Walking surveys for avifauna were also conducted to identify additional species not encountered during station counts. Walking surveys were conducted around both the Kāne‘ohe and Kailua WWTP’s, Bay View Golf Course, the public path along southern Nu‘upia ‘Ekahi Pond, the access road leading to the Kapa‘a Access Shaft, and Kāne‘ohe Bay Drive between the H-3 roundabout and Kailua WWTP. The avian phylogenetic order and nomenclature used in this report follow the *AOU Check-List of North American Birds* (American Ornithologists’ Union, 1998) and the 42nd through the 51st supplements to the Check-List (American Ornithologists’ Union, 2000; Banks, et al., 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010).

Listed Species

A review of published literature and field notes from *AECOS*, Inc. surveys in and near the project area was conducted to ascertain what if any federal Endangered Species Act (ESA) listed or state listed marine or avian species would be anticipated to be encountered at project work areas (most of the work for each alternative occurs far underground).

The Endangered Species Act (ESA) of 1973 [16 U.S.C. 1531-1544, 87 Stat. 884] mandates the protection of listed endangered and threatened species and their critical habitats. The Act gives jurisdiction over endangered terrestrial flora, fauna and birds to U.S. Fish and Wildlife Service (FWS) and jurisdiction over sea turtles and marine mammals to National Oceanic and Atmospheric Adminstration (NOAA) Fisheries. Under Section 7 of the Act, federal, state, and local agencies must consult with these organizations when threatened or endangered species exist in a project area.

Results

Avifaunal Surveys

The findings of the avian survey are consistent with the habitat present at the surveyed sites and with the general location of coastal windward O‘ahu. Generally, birds were sighted much more commonly at count stations and during walking at the Kāne‘ohe end as compared to the Kailua end of the project. A total of 180 individual birds representing 18 different species from ten separate families were recorded during the six station counts (Table 1). 14 of the species recorded are considered to be introduced species, naturalized in the Hawaiian Islands. Doves (Family Columbidae), Common Waxbills (*Estrilda astrild*), and the ubiquitous Common Myna (*Acridotheres tristis*) account for over 68% of individual birds recorded during station counts.

Table 1. List of bird species sighted during surveys
and their abundances at six count stations.

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	Common name	Status	ABUNDANCE Count Stations 1	2	3	4	5	6
CHORDATA, AVES	**BIRDS**							
AVES, ANSERIFORMES								
ANATIDAE								
Anas sp. Linnaeus	unid. duck	--	--	--	--	--	--	--
AVES, CICONIIFORMES								
ARDEIDAE								
Bubulcus ibis Linnaeus	Cattle Egret	Nat.	1	--	2	--	3	--
Nycticorax nycticorax Linnaeus	Black-crowned Night Heron; *ʻaukuʻu*	**Ind.**	--	--	--	--	--	--
CHARADRIIDAE								
Himantopus mexicanus knudseni Muller	Hawaiian Stilt; *aeʻo*	**Ind.**	--	1	--	--	--	--
Pluvialis fulva J. F. Gmelin	Pacific Golden Plover; *kolea*	**Ind.**	--	3	--	--	3	--
SCOLOPIDAE								
Calidris alba Pallas	Sanderling	**Ind.**	--	--	8	2	--	--
AVES, COLOMBIFORMES								
COLUMBIDAE								
Columba livia J. F. Gmelin	Rock Dove	Nat.	--	--	1	2	--	--
Geopelia striata Linnaeus	Zebra Dove	Nat.	--	5	9	4	5	2
Streptopelia chinensis Scopoli	Spotted Dove	Nat.	7	5	4	2	--	--
AVES, GALLIFORMES								
PHASIANIDAE								
Gallus gallus Linnaeus	Red Junglefowl	Dom.	--	--	--	3	--	--
AVES, PASSERIFORMES								
EMBERIZIDAE								
Paroaria coronata J. F. Miller	Red-crested Cardinal	Nat.	1	3	--	--	--	--
ESTRILDIDAE								
Amandava amandava Linnaeus	Red Avadavat	Nat.	--	--	--	--	--	2
Estrilda astrild Linnaeus	Common Waxbill	Nat.	26	14	2	2	--	6

Table 1 (continued).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	Common name	Status	ABUNDANCE Count Stations 1	2	3	4	5	6
ESTRILDIDAE (cont.)								
Lonchura atricapilla Viellot	Chestnut Mannikin	Nat.	2	3	--	--	--	2
Padda oryzivora Linnaeus	Java Sparrow	Nat.	2	3	--	--	--	--
FRINGILLIDAE								
Carpodacus mexicanus Muller	House Finch	Nat.	--	--	--	1	--	--
PASSERIDAE								
Passer domesticus Linnaeus	House Sparrow	Nat.	--	--	--	--	--	1
PYCNONOTIDAE								
Pycnonotus cafer Linnaeus	Red-vented Bulbul	Nat.		8	--	1	--	--
Pycnonotus jocosus Linnaeus	Red-whiskered Bulbul	Nat.	1	--	--	--	--	--
STERNIDAE								
Acridotheres tristis Linnaeus	Common Myna	Nat.	4	--	13	11	--	--

Legend

Status

End. – Native and unique to the Hawaiian Islands;
Ind. – indigenous; native to Hawaiʻi, but not unique to the Hawaiian Islands;
Nat. – naturalized; exotic, introduced to the Hawaiian Islands.
Dom. – domesticated; wild population not established .

Locations:

Sta.1 – entry gate Kāneʻohe WWTP.
Sta. 2 – east end Kāneʻohe WWTP.
Sta. 3 – center of western shore of Waikalua Fishpond.
Sta. 4 – pipe entry work area along Kāneʻohe Stream
Sta. 5 – H-3 roundabout/Kailua work area
Sta. 6 – Kapaʻa access shaft off Mōkapu (Saddle) Rd.

Three species observed during station counts are native to Hawaiʻi: Sanderling (*Calidris alba*) Plover (*Charadrius semipalmatus*), Hawaiian Stilt or *aeʻo* (*Himantopus mexicanus*), and the Pacific Golden Plover or *kolea* (*Pluvialis fulva*). One additional native species, the Black-crowned Night Heron or *ʻaukuʻu* (*Nycticorax nycticorax*) was observed during a walking survey near Nuʻupia ʻEkahi Pond. Several unidentified ducks were also observed in the pond as well as flying over the project work area beside Kāneʻohe Stream.

Although not detected during the course of this survey, it is possible that the Hawaiian endemic sub-species of the Short-eared Owl (*Asio flammeus sandwichensis*) or *pueʻo*, as it is known locally, forages near the project sites on occasion. The Oʻahu population of this species is listed as endangered under state endangered species statutes (DLNR, 1998), but it is not listed under the federal endangered species act.

Protected Species

Regional Overview

Table 2 provides a listing of listed species in the project vicinity. The Kailua (Aikahi) RWWTP is located adjacent to the 482-acre Nuʻupia Ponds Wildlife Management Area (WMA) on Marine Corps Base Hawaii. The ponds at Nuʻupia represent a primary breeding area for a population of 20 *aeʻo* or Hawaiian Stilt (*Himantopus mexicanus knudseni*), a species listed as endangered under both federal and state laws (Drigot, et al, 2001). The ponds provide foraging habitat for three other federally listed endangered species: Hawaiian Duck (*Anas wyvilliana*), Hawaiian Coot (*Fulica alai*), and Hawaiian Gallinule (*Gallinula chloropus sandvicensis*).

The presence of *honu* or Green sea turtle (*Chelonia mydas*) in Kāneʻohe Bay is well documented (Aguirre, 1992; Aguirre, et al, 1994, 1995; Brill, et al. 1995; Balazs, et al, 2000; Zamzow, 1998). The species was identified near the proposed project corridor in October of 2009 (*AECOS*, 2009). Turtle tracks were also present on deep (>35 ft) soft sediment along the proposed force main route (personal observation). Green sea turtles are protected by the ESA and the Hawaiian population is listed as threatened under both federal and state laws. The endangered Hawksbill turtle (*Eretmochelys imbricata*) is reported to occur historically in Kāneʻohe Bay (Balazs, 1978). Sightings of immature or adult hawksbills are uncommon in coastal waters of the Hawaiian Islands (Balazs, Katahira, and Ellis, 2000).

The endangered Hawaiian monk seal (*Monachus schauinslandi*) is reported to visit Kāneʻohe Bay. In April of 1996, a pregnant monk seal hauled out along the shoreline west of Pyramid Rock (outside the Bay) to successfully birth and ween her pup (Drigot, et al, 2001). Monk seal populations are declining at an average rate of 4% per year with about 1100 individuals present throughout the Hawaiian Islands (Wilson, 2010). Most of these individuals reside in the Northwest Hawaiian Islands and the proposed project work areas do not include any sand shorelines, which are occasionally utilized by monk seals in the main Hawaiian Islands.

Table 2. List of protected species occurring in Kāneʻohe Bay and their anticipated occurrence at proposed project work areas.

PHYLUM, CLASS, ORDER FAMILY *Genus Species*	Common Name; *Hawaiian Name*	ESA Listing	Project Occurrence
CNIDARIA, ANTHAZOA			
SCLERATINIA			
ACROPORIDAE			
Montipora dilatata	irregular rice coral	SOC	No
BRACHIOPODA			
INARTICULATA			
LINGULIDA			
LINGULIDAE			
Lingula reevi	inarticulate brachiopod	SOC	No
CHORDATA, REPTILIA			
TESTUDINES			
CHELONIIDAE			
Chelonia mydas	green sea turtle; *honu*	T	Force main emergency plan
Eretmochelys imbricata	hawksbill turtle; *ʻea*	E	No
MAMMILIA CARNIVORA			
PHOCIDAE			
Monachus schauinslandi	Hawaiian monk seal; *`ilio holo i ka uaua*.	E	No
AVES, ANSERIFORMES			
ANATIDAE			
Anas wyvilliana	Hawaiian Duck; *koloa maoli*	E	Nearby/overhead Kāneʻohe/Kailua WWTPs
AVES, GRUIFORMES			
RALLIDAE			
Fulica alai	Hawaiian Coot; *alae keʻokeʻo*	E	Nearby/overhead Kāneʻohe/Kailua WWTPs

Table 2 (continued).

PHYLUM, CLASS, ORDER FAMILY *Genus Species*	Common Name; *Hawaiian Name*	ESA Listing	Project Occurrence
RALLIDAE (continued)			
Gallinula chloropus sandvicensis	Hawaiian Gallinule *alae ʻula*	E	Nearby/overhead Kāneʻohe/Kailua WWTPs
AVES, CICONIIFORMES			
CHARADRIIDAE			
Himantopus mexicanus knudseni	Hawaiian Stilt; *aeʻo*	E	Nearby/overhead Kāneʻohe/Kailua WWTPs

Legend
E – Endangered species; Population listed as endangered, it illegal to "take" (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to do these things) that species
T – Threatened species; Population listed as threatened, it illegal to "take" (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to do these things) that species
SOC – Species of concern. A "Species of Concern" is a species or vertebrate population for which there is concern or great uncertainty about its status. Species of Concern are not protected by the ESA.

A species of concern, listed by the National Oceanic and Atmospheric Administration (NOAA) and known to occur within Kāneʻohe Bay, is irregular rice coral (*Montipora dilatata*). This species has a very small known population within the Bay as only three colonies were identified during extensive surveys in 2000 (NOAA, 2007). However, current taxonomic status of the species is unclear and therefore actual distribution poorly known. This species may be confirmed to have additional populations in the Northwest Hawaiian Islands.

Another species of concern from Kāneʻohe Bay is the inarticulate brachiopod, *Lingula reevi*. This species was found to be very abundant in 1967-69 in the area of the project marine surveys; Worcester (1969) found densities of up to 500 individuals/m^2 at sites on reef flats off the southeast shore of Kāneʻohe Bay. The population of this species has since plummeted (Hunter, et al., 2008, 2009). Surveys in 2004 found that the highest *L. reevi* densities—in the same areas sampled in 1967-69—had fallen to 4 individuals per m^2. In 2007, no brachiopods occurred in this area, and the species was absent at eight of twelve sites where they were once common to abundant in the late 1960s. It is highly probable that these drastic reductions in *L. reevi* are due to the reduction in their food source resulting from cessation of sewage (nutrient) inputs into the Bay and the transition of Bay waters away from a eutrophic state.

Protected Species in Project Work Areas

The under Kāneʻohe Bay force main alternative will require work areas on land-located at the Kāneʻohe and Kailua WWTPs, a work area at the H-3 roundabout, trenching along Kāneʻohe Bay Drive, and (potentially) emergency work areas in south Kāneʻohe Bay. The underground gravity tunnel will require work area at both WWTPs and at an access shaft located near the BWS water tank on Mokapu (Saddle) Rd.

Published reports confirm the presence of four endangered waterbirds near the proposed work areas at the Kailua WWTP and along Kāneʻohe Bay Drive. Avian surveys conducted in November 2010 confirm the presence of the endangered Hawaiian Stilt flying above the Kāneʻohe WWTP and unidentified ducks (that may be hybrid Hawaiian Duck) near the work areas at both the WWTPs. The primary threats to all four endangered waterbirds found near the project are: habitat loss, introduced predators, altered hydrology, proliferation of non-native invasive plants, avian diseases, and environmental contaminants (Mitchell et al, 2005). The project, as planned, will not enhance any of these threats to endangered waterbirds or their adversely impact habitats.

Endangered waterbirds are not likely to frequent the proposed work areas largely due to the proximity of utilizable habitat nearby (Waikalua Fishpond in Kāneʻohe; Nuʻupia Ponds in Kailua). Sightings of endangered waterbirds may occur as individuals or flocks transit through the air above the work areas. Given the stable and increasing populations of all four endangered waterbirds near the project (Mitchell et al., 2005), and the fact that project construction work will not attract nearby bird life, Best Management Practices (BMP) specific to endangered waterbirds—other than general avoidance when encountered—do not seem warranted.

Recent survey work in Kāneʻohe Bay, conducted by *AECOS*, Inc., indicates that Green sea turtles (*C. mydas*) do utilize marine waters above the force main route. Turtle abundance in south Kāneʻohe Bay is not known, but *AECOS*, Inc. surveys in 2009 involving 10 days of survey work for teams of two to four divers resulted in but a single turtle sighting. The marine surveys did confirm the presence of seagrass beds along the route. The diet of green turtles in the Main Hawaiian Islands is dominated by the naturalized rhodophyte alga, *Acanthophora spicifera*, and species from the algal genera *Hypnea*, *Pterocladiella*, and *Cladophora*, although two sea grasses (*Halophila hawaiiana* and *Halophila decipiens*) are an important component of the diet in turtles from Kāneʻohe Bay (Arthur and Balazs, 2008; Russell and Balazs, 2009).

Impacts to Protected Species

The project as planned will not affect any marine or protected species. However, a contingency 20 x 20 ft (6 x 6 m) emergency access shaft in Kāneʻohe Bay—to be constructed by driving sheet piles and excavating enclosed sediment—for equipment realignment/repair or removal of an obstruction as needed, may have impacts. This contingency plan will require the use of a work barge, landing craft, or pontoon assembly to access the shaft area and a vibratory or hydraulic driver to place sheet piles. The assembly, use, and removal of such an emergency shaft would potentially impact Green sea turtles (*C. mydas*) foraging or resting near the shaft site. Further, damage to sea turtle foraging resources could occur if this work site ended up in an area supporting a sea grass bed. BMPs to ensure protection of the threatened Green sea turtle should be included as part of the under-Bay emergency work area contingency plan. These BMPs would also protect hawksbill turtle in the unlikely event that this species is encountered during construction.

Impacts to threatened Green sea turtle and turtle habitat from the construction, use and removal of the emergency shaft may include:

- Loss or degradation of foraging, resting, or shelter habitat.
- Increase motorized vessel traffic.
- Proliferation of non-native invasive algal species.
- Degradation of habitat or water quality by dredging/excavation activity.
- Elevated noise levels during driving of sheet piles and other work.

These impacts to sea turtles will be both temporary and brief. Construction, access, and removal of an emergency access shaft will likely be completed in a matter of hours or days. No long-term adverse impacts to sea turtles or their habitat are anticipated to occur from construction of a temporary access shaft, although areas identified as “sensitive” on the marine survey report (AECOs, 2010b) could suffer long-tem adverse impacts.

Best Management Practices for Sea Turtles

Research into turtle hearing is limited, but available information suggests that they are low frequency specialists, with Green sea turtles believed to be most acoustically sensitive between 200 and 700 Hz (Ridgway et al, 1969), a frequency range that overlaps with noise associated with driving sheet piles (CalTran, 2007). To reduce adverse impacts to turtles the project could limit noise/acoustic disturbance to ensure that sound emanation from the driving of sheet piles is below the temporary threshold shift (TTS) of 180 to 190 dB re 1 microPascal/m (rms) for marine mammals (see NOAA, 2005). Sea turtles are believed to be less sensitive to sound than marine mammals relying more heavily on visual cues, rather than auditory input (Hazel, et al. 2007; Ridgeway et al. 1969).

Underwater sound energy travels outward spherically in all directions, and dissipates through mechanisms such as spreading, scattering, and absorption (Bradley and Stern 2008). The existing conditions in south Kāneʻohe Bay, like turbid water to scatter sound and a soft sediment sea floor to absorb sound will likely aid this process and shorten the distance sound travels before dissipating below TTS.

Published methods to limit sound travel during projects in marine waters include physical barriers, such as silt containment devices and bubble curtains created by releasing air from pipes, tubing or hosing placed on the seafloor surrounding all or a portion of the work area (CalTrans, 2007). Utilizing "soft-starts" with pile-driving by starting at very low impact velocities and slowly building up to full energy may allow sea turtles and other marine life to travel away from the area before full acoustic levels are reached. Halting pile-driving when protected species are within the 50 m (164 ft) range, a conservative estimate, may prevent permanent hearing damage to sea turtles caused by exposure to acoustic disturbance in the permanent threshold shift (PTS) range.

Sea turtle research indicates that Green sea turtle, like other turtle species, cannot be expected to consistently notice and avoid vessels that are traveling faster than 2 knots (Hazel, et al. 2007). Directing vessels operators to limit speeds to five knots or less when transiting to work areas, keeping at least 50 m away from sea turtles when vessels are under way, and slowing vessel speed to below 2 knots when turtles are in the direct vicinity can limit the potential for vessel impacts to sea turtles.

The presence of gorilla ogo (*Gracilaria salicornia*) in Kāneʻohe Bay is well documented (AECOS, 2009, 2010b; Coles, et al, 2002). Any work equipment in contact with the seafloor or reef surfaces in Kāneʻohe Bay should be inspected and cleaned of marine life before being removed from or relocated within the bay to avoid spreading this invasive species.

Following is a list of general Best Management Practices (BMPs) typically issued by federal regulatory agencies that can be implemented to prevent adverse impacts to sea turtles and other marine life in Kāneʻohe Bay during the project construction phase:

1. Turbidity and siltation from project-related work should be minimized and contained to within the vicinity of the site through the appropriate use of effective silt containment devices and the curtailment of work during adverse tidal and weather conditions.
2. Any construction-related debris that may pose an entanglement hazard to marine protected species must be removed from the project site if not actively being used and certainly at the conclusion of construction work.
3. All project-related materials and equipment placed in the water should be free of pollutants.
4. No project-related materials (fill, revetment, rock, pipe, etc.) should be stockpiled in the water (intertidal zones, reef flats, stream channels, etc.).
5. No contamination (trash or debris disposal, alien species introductions, etc.) of marine (reef flats, lagoons, open ocean, etc.) environments adjacent to the project site should result from project-related activities.
6. Fueling of project-related vehicles and equipment should take place away from the water. A contingency plan to control the accidental spills of petroleum products at the construction site should be developed. Absorbent pads, containment booms, and skimmers will be stored on-site to facilitate the cleanup of petroleum spills.
7. Underlayer fills will be protected from erosion with core-loc units (or stones) as soon after placement as practicable.
8. Attempts must be made to prevent discharge of dredged material into the marine environment during the transporting and off-loading of dredged material.
9. Return flow of or run-off from dredged material stored at inland dewatering or storage sites must be prevented.
10. A visual survey of the project area (by either the contractor or state personnel) must be performed just prior to commencement or resumption of construction activity to ensure that no state or ESA protected species are in the area. If protected species are detected, construction activities must be postponed until protected species voluntarily leave the area.
11. If any ESA-listed species enters the area during construction activities, all activities must cease until they voluntarily depart the area.
12. All on-site project personnel must be apprised of the status of any ESA listed species potentially present in the project area and the protections afforded to those species under federal laws.

13. Any incidental take of marine mammals must be reported immediately to NOAA 24-hour hotline at 1-888-256-9840. Any injuries to sea turtles must be reported immediately to NOAA at 1-808-983-5730. Information must include the name and phone number of a point of contact, location of the incident, and the nature of the take and/or injury.

Conclusions

The under-Bay force main alternative will require work areas located at the Kāneʻohe and Kailua WWTPs, a work area at the H-3 roundabout, trenching along Kāneʻohe Bay Drive, and may require emergency work areas at some locations in south Kāneʻohe Bay. The underground gravity tunnel alternative will require work area at both WWTPs and at an access shaft located near the BWS water tank on Mokapu (Saddle) Rd. The only work location that is anticipated to have potential for impact to species listed by either state or federal protective regulations is any contingency (emergency) access shafts in Kāneʻohe Bay. As needed, the emergency shaft will need to implement special BMPs to protect sea turtles, water quality, and the marine environment generally at the access shaft location.

The Kāneʻohe and Kailua WWTPs and the work areas along Kāneʻohe Bay Drive are close to waterbird habitats, but the proposed work should not result in any adverse impacts on any of these species or their habitats. No ESA listed species is anticipated to utilize the work area near the Kapaʻa Access Shaft.

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Appendix E

Archaeological Assessment:
Proposed Kaneohe – Kailua Force Main No. 2
Kaneohe, Koolaupoko, Oahu
Aki Sinoto Consulting LLC
November 2010

ASC111910

ARCHAEOLOGICAL ASSESSMENT:

PROPOSED KANE`OHE-KAILUA FORCE MAIN NO. 2
KANE`OHE, KO`OLAUPOKO, O`AHU

November 2010

Aki Sinoto Consulting, LLC
2333 Kapiolani Blvd., No. 2704
Honolulu, Hawai`i 96826

ASC111910

ARCHAEOLOGICAL ASSESSMENT:

PROPOSED KANE`OHE-KAILUA FORCE MAIN NO. 2
KANE`OHE, KO`OLAUPOKO, O`AHU

for

Austin, Tsutsumi and Associates, Inc.
501 Sumner Street, Suite 521
Honolulu, Hawai`i 96817-5031

by

Aki Sinoto

and

Paul Titchenal

November 2010

Aki Sinoto Consulting
2333 Kapiolani Blvd., No. 2704
Honolulu, Hawai`i 96826

ABSTRACT

An archaeological assessment, primarily involving review of pertinent previously completed studies, archival searches for documents, and on-site surface survey, was undertaken by Aki Sinoto Consulting of Honolulu at the request of Austin Tsutsumi and Associates, Inc. (ATA), also of Honolulu. This assessment report was prepared in conjunction with an environmental impact statement (EIS) being prepared by the City and County of Honolulu (CCH) for the proposed Kane`ohe/Kailua Force Main Number 2 (KKFM2) Project. The proposed undertaking, mandated by a 1995 Federal Environmental Protection Agency consent decree seeks to connect the existing Kane`ohe Effluent Pump Station in Waikalua to the existing Kailua Regional Waste Water Treatment Plant in Aikahi by a transmission pipeline traversing under the sea floor of Kane`ohe Bay. The construction will employ either Horizontal Directional Drilling or Micro-tunneling technologies to install nearly 10,000 linear feet of jacketed pipeline under the bottom of the bay.

Three previous archaeological studies have been completed within the Waikalua or southwestern end of the project area. These studies all dealt with the proposed expansion of the Bay View Golf Course and the preservation of Waikalua-loko fishpond (SIHP Site 50-80-10-349). No previous studies have been completed within the boundaries of the Aikahi or northeastern end of the project area.

Subsurface testing was precluded during the current undertaking in view of the limited open-trenching proposed as well as the occurrence of project corridor segments in areas where subsurface testing prior to construction was unfeasible. Such areas included Federal lands, the right-of-ways of existing public roadways, and in the existing waste water treatment facilities comprising both ends of the project area. Additionally, since two separate, but potentially viable options are included in the upcoming draft EIS document, the decision was made to conduct subsurface testing only after the selection is made. A combination of preconstruction testing and archaeological monitoring of construction activities is expected to fulfill the historic preservation review requirement for this Kane`ohe-Kailua Force Main No. 2 project.

A cultural impact assessment (CIA) was prepared under separate cover and shall be included in the upcoming Draft EIS as an appendix.

INTRODUCTION

At the request of Austin Tsutsumi and Associates, Inc. of Honolulu; Aki Sinoto Consulting of Honolulu, undertook an archaeological assessment in conjunction with the Kane`ohe-Kailua Force Main No. 2 (KKFM2) Project being proposed by the City and County of Honolulu (CCH). The proposed project seeks to connect the existing Kane`ohe Effluent Pump Station (KEPS) in Waikalua with the existing Kailua Regional Wastewater Treatment Plant (KRWTP) in Aikahi with a new force main waste-water transmission line traversing under the bottom of Kane`ohe Bay. A background description of the project area, a summary compilation of resultant information from a search and review of the results of previous archaeological studies undertaken in the immediate vicinity of both terrestrial segments of the proposed transmission corridor, evaluations of specified areas of potential effect based primarily on available information, and the formulation of recommendations for mitigation procedures are included here.

PROJECT AREA

The project area occupies the coastal portions of Kane`ohe *ahupua`a*, Ko`olaupoko District, O`ahu Island and consists of the two terrestrial segments of the transmission corridor and the major under-bay segment (Figs. 1 & 2). The total length of the corridor measures roughly 13,500 linear feet (4114.80 m) with the Waikalua land segment about 1000 linear feet (304.80 m), the Aikahi land segment about 2500 linear feet (762 m), and the segment beneath the bay about 10,000 linear feet (3048 m). The archaeological concerns focus on the terrestrial segments at both ends of the corridor.

The Waikalua terrestrial segment occurs within portions of three parcels (Fig. 3); the Kane’ohe Effluent Pump Station (TMK: (1) 4-5-30:36), City and County property along Kane`ohe Stream (TMK: (1) 4-5-30:47); and the former Bay View, LLC property currently owned by Central Pacific Bank (TMK: (1) 4-5-30:1). The Aikahi terrestrial segment traverses lands owned by the Federal Government including the H-3 interchange where the connection with the underbay segment is slated to occur (TMK: (1) 4-4-08:1); the right-of-way of Kane’ohe Bay Drive, and the Kailua Regional Wastewater Treatment Plant (TMK:(1) 4-4-11:81) owned by the City and County of Honolulu (Figs. 4 & 5).

The connecting segment to the KEPS on the Waikalua end is slated as an open trench installation over roughly 1000 linear feet in length, while approximately 2500 linear feet of the Aikahi end connection to the KRWTP may be either open trenching or micro-tunneling.

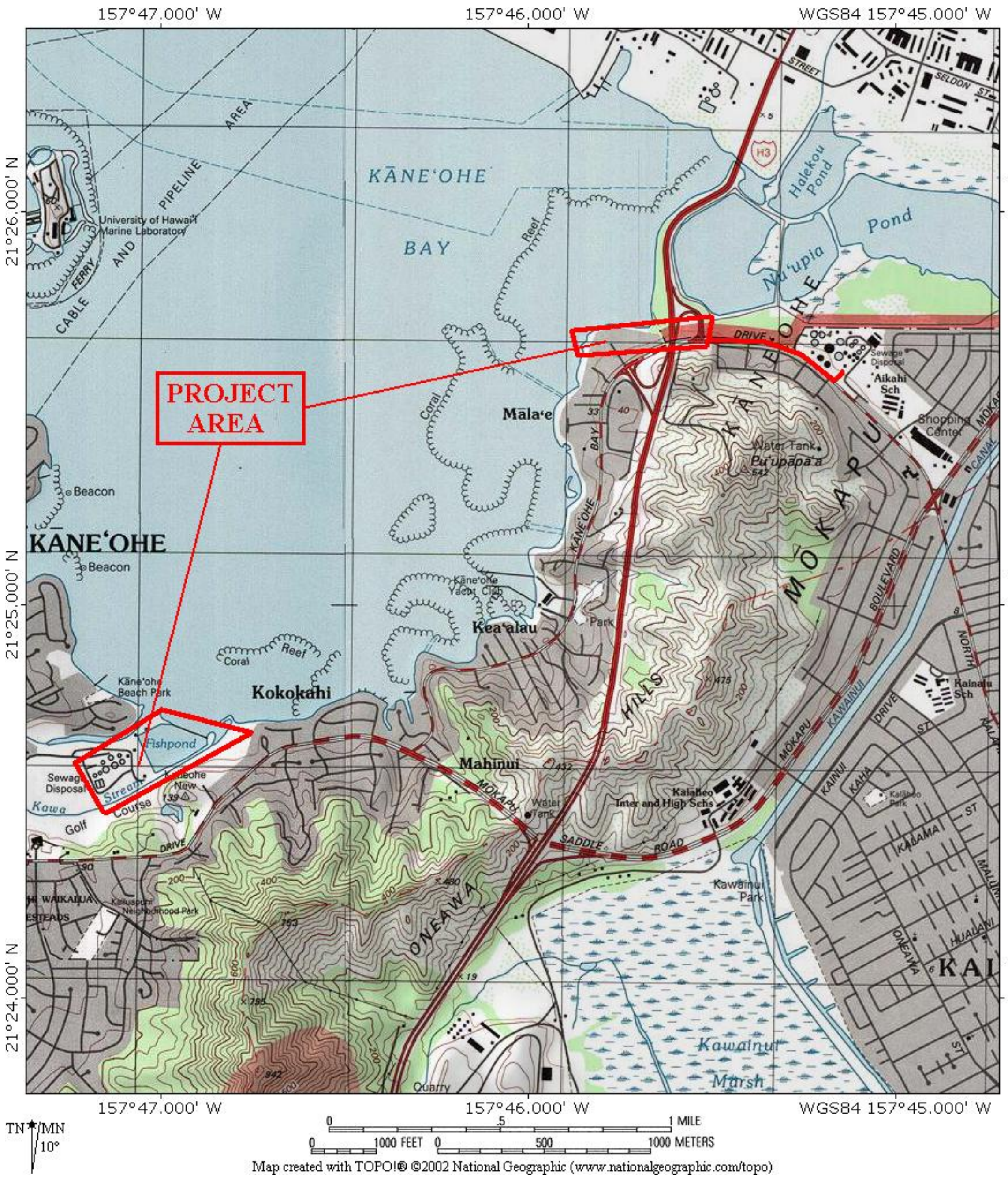

Figure 1. Terrestrial Portions of the Project Area on USGS Kaneohe Quadrangle

Figure 2. Aerial Overview of the Kane`ohe Bay Alternate Project Area

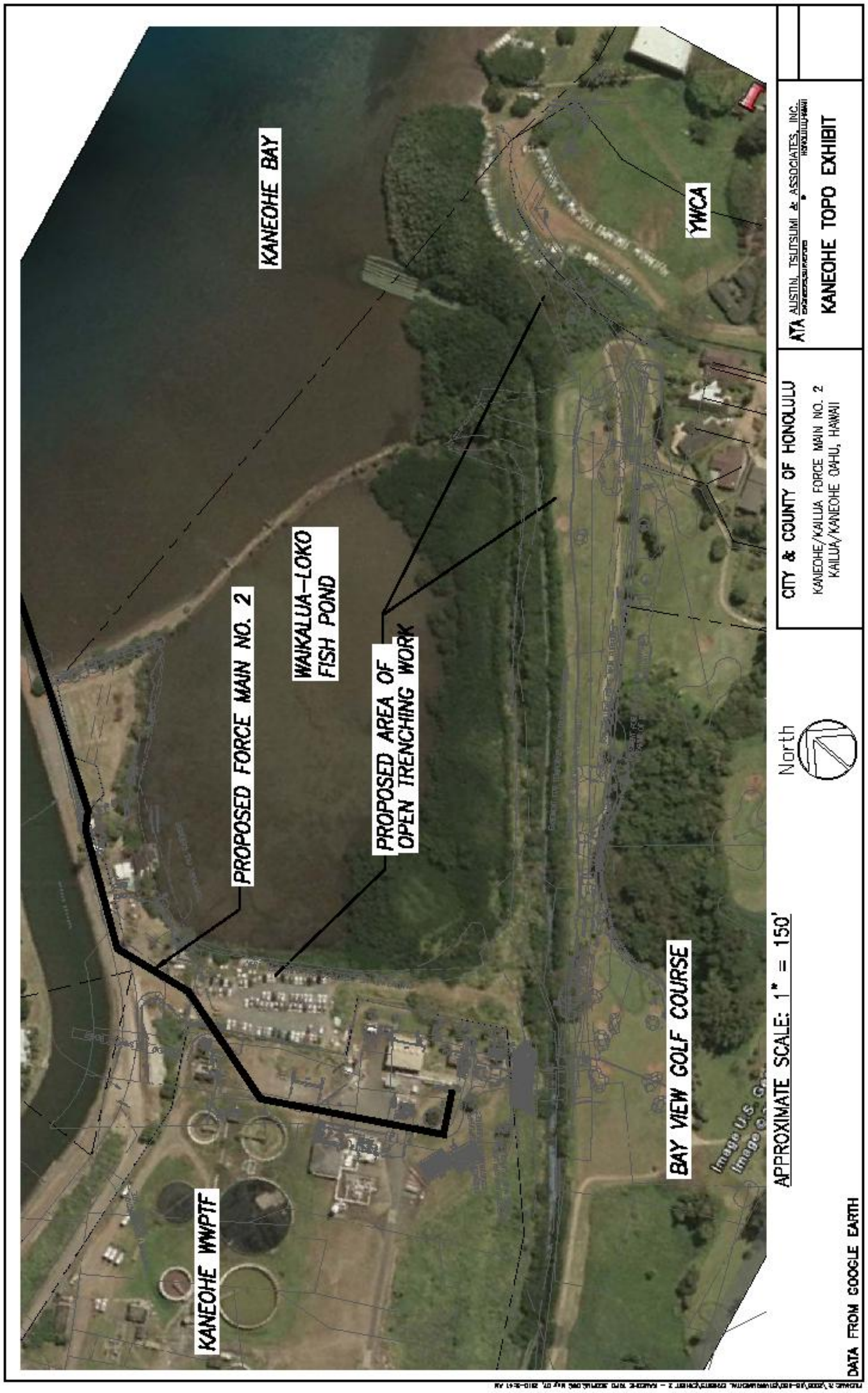

Figure 3. Detailed Aerial Overview of the Waikalua End of the Project Area

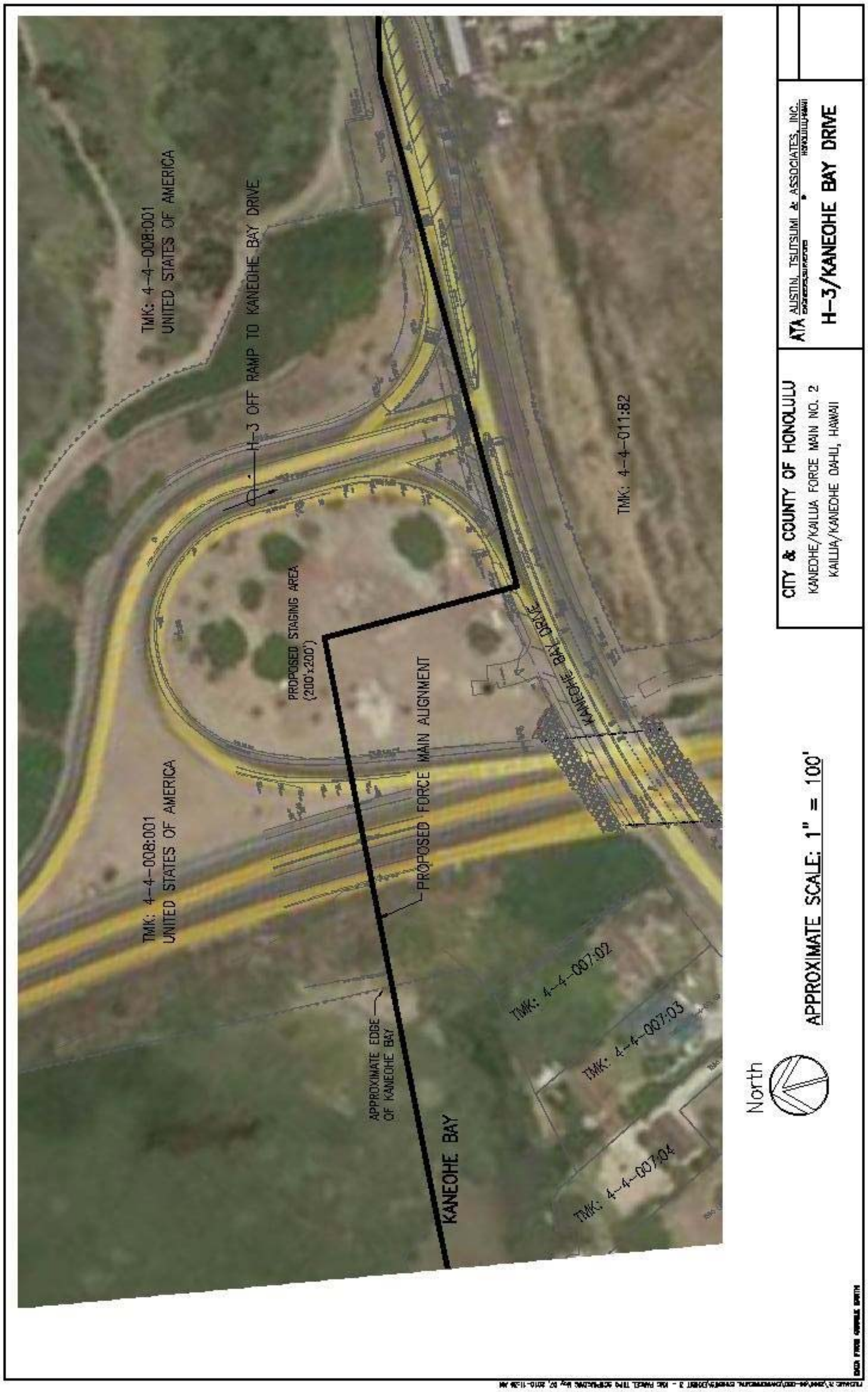

Figure 4. Detailed Aerial Overview of the Mokapu End of the Project Area, West Half

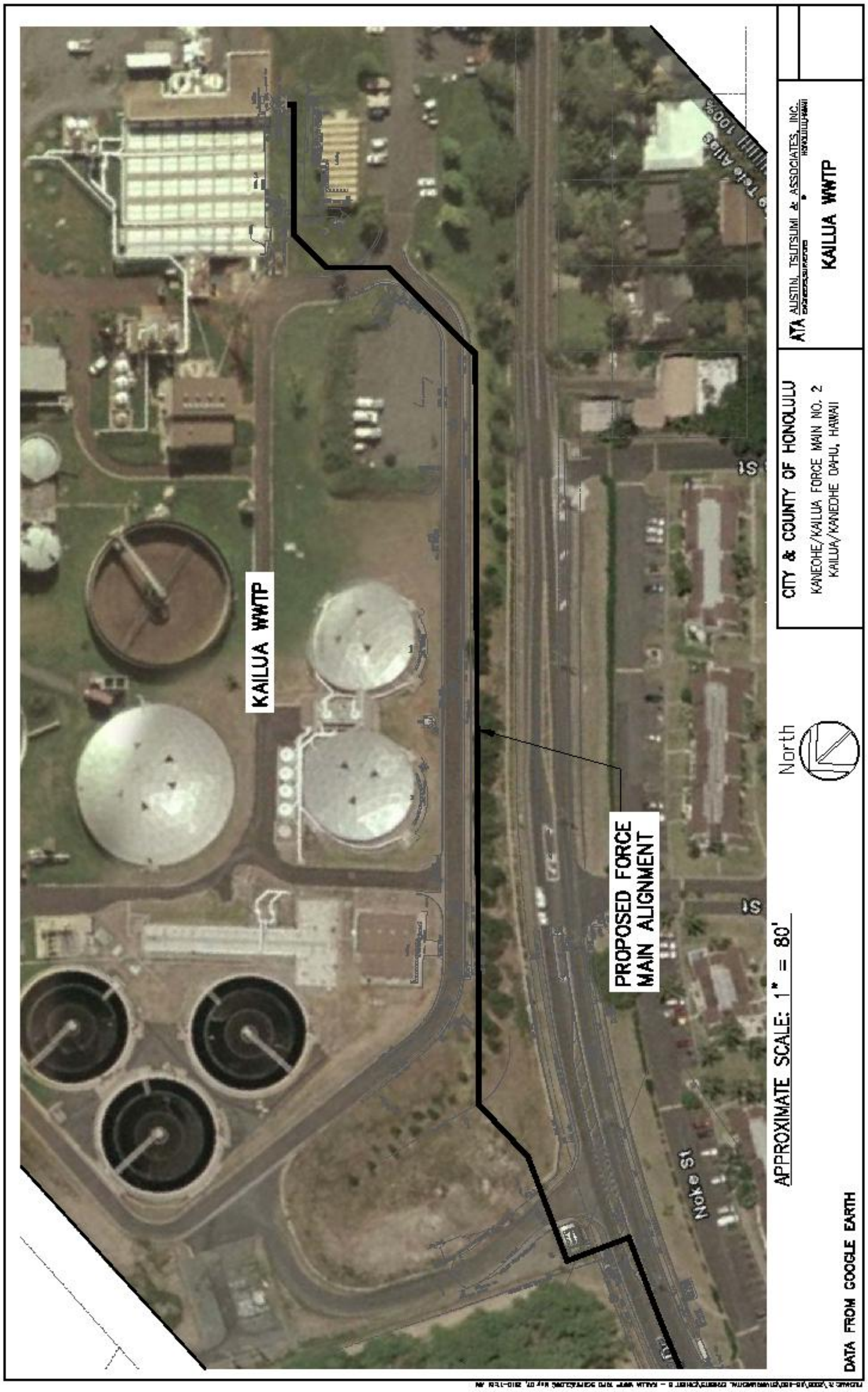

Figure 5. Detailed Aerial Overview of the Mokapu End of the Project Area, East Half

ENVIRONMENT

A brief description of the general Kane`ohe region and Kane`ohe Bay followed by a summary of environmental data for the subject project area will be presented in this section.

Kane`ohe

The many attributes of the windward lands surrounding Kane`ohe Bay make O`ahu unique in contrast to the other major islands of the Hawaiian chain. Handy and Handy (1972:436) list eight characteristics that define this uniqueness:

1. Bay and reef coastline which make cultivation feasible right to the shore where coconuts thrive;
2. extensive wet-taro plantations with ample water;
3. swampy areas where taro and fish were raised;
4. sloping piedmont and level shore-side areas well adapted to sweet potato farming;
5. ample streams whose mouths are ideal seaside spawning pools;
6. fishponds in which systematic fish farming was practiced;
7. upstream terraced streamside lo`i; and
8. accessible forested slopes and uplands, for woodland supplies and recourse in famine times.

These researchers continue that, "location and terrain made this type of area and its contiguous localities one of the early centers of colonialization as is evidenced by lore, and hence a center of myths and legends… " (Handy and Handy 1972:437). Kane`ohe *ahupua`a* is described as, "…an area of little hills with many small streams between them…The broken topography of Kane`ohe arranges the areas of flatland like chains of pockets connecting along its stream channels between hills" (ibid. 1972:455). The *ahupua`a* is likened to "a vast green ampitheater below the serrated sheer cliffs…" and "…the stream beds along the upper courses, there is little evidence of systematic terracing observable in these areas, as might have been expected. The lowland *lo`i* areas were so extensive that evidently the more laborious terracing of the interior slopes was not regarded by the early Hawaiians as necessary" (ibid. 1972:456). The narrative continues on to describe the neighboring Kailua *ahupua`a* as the "seat of the high chiefs of Ko`olaupoko from very early times. The beach, the bay, and living conditions were and are very attractive. Waimanalo and Kane`ohe, both rich farming areas, were neighboring…Undoubtedly further reasons for the attractiveness of Kailua as a place of residence for an *ali`i nui* with his large entourage were the great natural fishponds, Ka`elepulu and Kawainui, and the complex of artificial salt-water ponds that are between Kailua and Kane`ohe in the Mokapu area: Halekou, Nu`upia, and Kaluapuhi" (ibid. 1972:457).

Kane`ohe Bay

Kane`ohe Bay measuring about 8 miles in length and 2.6 miles in width encompasses roughly 11,000 acres at mean sea level and constitutes the largest sheltered body of water in the main Hawaiian Islands. The nine *ahupua`a* bordering the bay from east to west are; Kane`ohe, He`eia, Kahalu`u, Waihe`e, Ka`alaea, Waiahole, Waikane, Hakipu`u, and Kualoa. Three marine zones occur in the bay; a fringing reef, lagoon, and a barrier reef. Fringing reefs occur in the inshore zone along the shoreline, patch reefs occur within the lagoon, and the barrier reef complex extends across the mouth of the bay. The sand flat, more commonly referred to as the sand bar, is part of the barrier reef system. Three distinct areas within the bay are designated the north, central, and south bays. The south bay within which the current project area is located manifests the most restricted circulation, the most impact from adjacent land uses, and the lowest average salinity.

Multiple episodes of man-made impacts occurred in the bay commencing with the prehistoric fishponds constructed by the early Native Hawaiians along its shoreline. Subsequent compounded direct and indirect activities during the historic and modern periods have adversely impacted its geography, biology, and turbidity. The majority of the WWII era dredging took place in the south bay which is also surrounded by the most developed shoreline including residential, commercial, and industrial areas. The bay has been impacted by the various effects of urbanization in the period following WWII. Until 1977-78, sewage was being discharged into the bay. The northern portion of the south bay on Mokapu Peninsula is the Kane`ohe Marine Corps Air Station and some of the bay areas are restricted from public access and use. Moku O Loe, or Coconut Island, occupies the boundary between the south and central bays (Kan`ohe Bay Master Plan 1992:9-10).

Project Area

The project area can be divided into three segments, the terrestrial segment at the Waikalua end, the marine segment under Kane`ohe Bay, and the terrestrial segment at the Aikahi end (see Figs. 1 & 2). The marine segment is well covered in the marine sub-consultant's and engineering reports, thus the subject of this report is the terrestrial segments comprising the Waikalua (southwest) and Aikahi (northeast) ends of the project corridor.

The Waikalua end is largely comprised of a modified estuarine landform located between Kawa Stream on the south and Kane`ohe Stream on the north (see Fig. 3). A series of traditional Hawaiian fishponds represent the earliest man-induced modification of the shoreline.

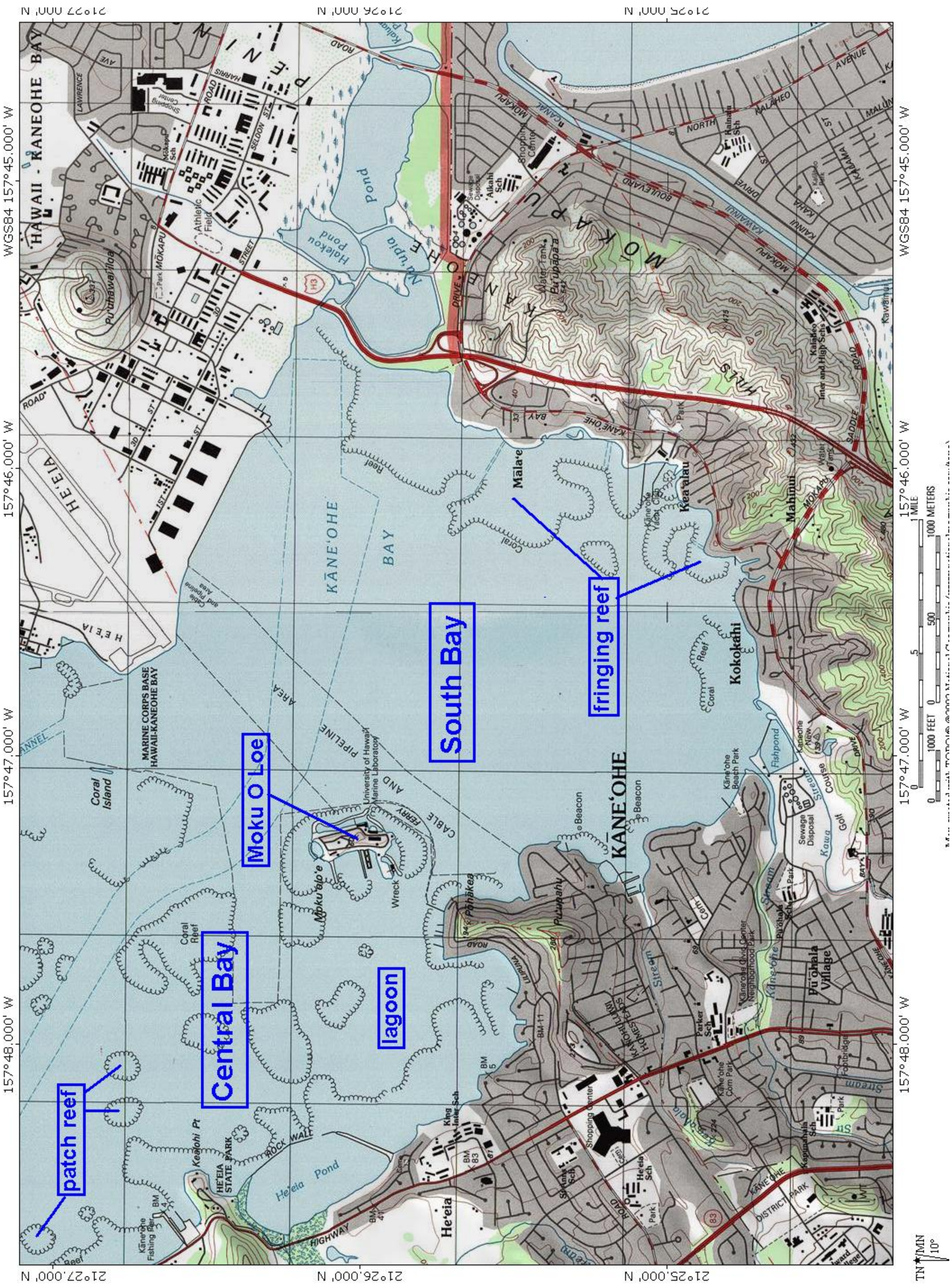

Figure 6. Kane`ohe Bay: South and Central Bays with Reef Types

Three of these ponds are within the project area boundaries, Waikalua Loko, Waikalua, and Keana Fishponds. Keana fishpond has been filled in and may have been destroyed. Waikalua Loko is currently the sole wholly intact pond with only the northeastern portion of Waikalua Fishpond visible (see fig. 3). Just inland of the pond is low-lying, level land where wetland cultivation of taro was undertaken by indigenous Hawaiian farmers. These areas were later modified for the cultivation of rice by immigrant Chinese farmers who also began commercial fish farming using the existing fishponds. Later the pond-field areas were filled for residential development and an elementary school (Puuohala) and waste water pumping station were constructed. The adjoining area north of Kane`ohe stream is occupied by residential development and the area to the south of Kawa Stream is the existing Bay View golf course.

Currently, the Waikalua area contains beach, shoreline, and wetland vegetation regimes consisting primarily of *hau* (*Hibiscus tiliaceus*), *milo* (*Thespesia populnea*), red mangrove (*Rhizophora mangle*), and false *kamani* (*Terminalia catappa*), together with common grasses and weeds. The presence of the oriental mangrove (*Bruguiera gymnorrhiza*) also reported to be in the Kane`ohe Bay region has not been confirmed within the project area. A comprehensive botanical survey was previously completed for this area (Linney and Char 1989).

The soils represented in the Waikalua area (Fig. 7) include; Hanalei silty clay (0-2% slopes), a poorly drained soil derived from basic igneous rocks developed in alluvium, that occurs in flood plains, with moderate permeability, slow runoff, and slight erosion hazard, but with a flooding hazard; Kane`ohe silty clay (8-15% slopes), a well-drained soil on alluvial fans on windward O`ahu, developed in alluvium and colluvium and derived from basic igneous rocks, and with moderately rapid permeability, medium runoff, and moderate erosion hazard; and Papaa clay (6-20% slopes), a well-drained soil formed in colluvium and residuum derived from basalt, that occur on uplands in O`ahu, with rapid permeability, slow to medium runoff, and slight to moderate erosion hazard (Foote et al. 1972: 38, 60, & 110).

A marine, estuarine, and stream study (Brewer/Brandman Associates 1989) observed salinity in Kane`ohe and Kawa Streams and also the nearshore waters of the bay near the stream mouths. This showed Kawa Stream to have a “salinity-stratified environment” (ibid. 1989:8) meaning that a differing range of salinities influenced by tidal action occurred between the surface (0 – 3.8 ppt) and bottom (16.25-23.5 ppt) waters of the stream. Similar stratification in salinity was not evident

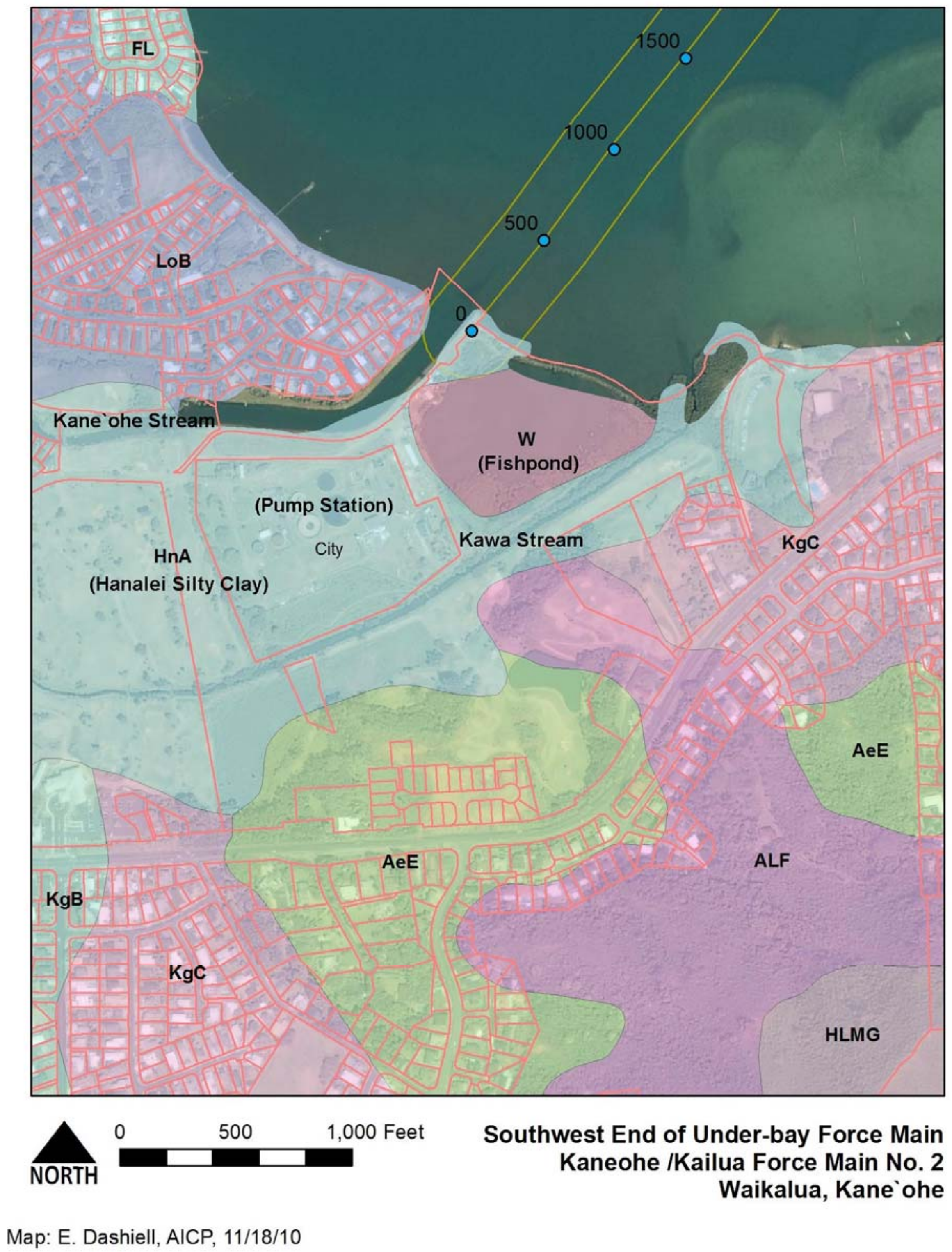

Figure 7. Soils in the Waikalua End of the Project Area

for Kane`ohe Stream attributed to a wider, more exposed stream mouth which promoted a high degree of vertical mixing from prevailing winds (ibid. 1989:9). Significantly, the near shore waters of the bay; due to influences from tidal fluctuation, surface runoff, and subtidal and intertidal groundwater discharges; showed a wide variation in salinity from near full strength seawater to freshwater (ibid. 1989:10). Within Waikalua Loko proper, students from the Marine Options Program of Windward Community College gathered salinity data in 1975 (30-36 ppt) and 1995 (30-37 ppt). The areas near the two *makaha* produced ranges similar to the near shore waters due to a more rapid circulation pattern in comparison with other portions of the pond which were designated as "super saline" areas due to the decreased circulation and regular influx of freshwater (Dashiell 1995:2). In November of 2010, Professor David Krupp and his Marine Sciences students from Windward Community College took salinity readings in each of four sampling stations both within the pond and in near shore localities within the bay. The readings which were conducted in the afternoon close to high tide ranged from 26.9 to 28.2 ppt within the pond and from 6.5 to 11.8 ppt in the nearshore areas in the bay. These results indicate the salinity readings to be similar over time and that the water in the pond in all cases showed a much higher range of salinity than the nearshore waters of the bay.

The Aikahi end of the project area, located on the western half of the Mokapu Peninsula isthmus, consists of a mangrove thicket at the shoreline, to the east is a previously modified area for the H3 Freeway interchange fronting the causeway leading to the Kane`ohe Marine Corp Base Hawaii main gate, further east is the Kane`ohe Bay Drive right-of-way, and beyond that the project corridor runs along a roadway within the existing Kailua Regional Wastewater Treatment Plant roughly paralleling the southwest boundary of the plant (see Figs. 4 & 5). The expansive Nu`upia fishpond occurs to the north of the project corridor (see Fig. 1). Historically, the Mokapu area was largely pastureland and during the years following WWII, the area south of Kane`ohe Bay Drive was developed as residential lots and subdivisions.

Currently, the western portion of the Aikahi segment contains beach and shoreline vegetation, consisting primarily of red mangrove with common grasses, weeds, and scrub. Along the eastern portion, the vegetation consists primarily of scrub *kiawe* (*Prosopis pallida*) and *koa haole* (*Leucaena glauca*) within the Marine base beyond the fenceline, and landscape hedge plantingsand grass along the southwest boundary of the Kailua Regional Wastewater Treatment Plant. A low mock orange (*Murraya paniculata*) hedge fronts the cmu-block wall along Kane`ohe Bay Drive and a stand of ironwood (*Casuarina equisetifolia*) trees line the area behind the wall. A few large monkey-pod trees (*Samanea saman*) occur within the grounds of the treatment plant.

The soils represented in the Aikahi area (Fig. 8) include; Kokokahi clay (6-12% slopes), a moderately well-drained soil on alluvial fans and talus slopes on Oahu, that developed in colluvium and alluvium derived from basic igneous rock, with slow to moderately-slow permeability, medium runoff, and slight to moderate erosion hazard; Jaucus sand, saline (0-12% slopes), an excessively drained, calcareous soil on coastal plains adjacent to the ocean and developed in wind and water deposited sand from coral and seashells, occurring where the water table is near the surface (within 30 inches) and the salts have accumulated, normally includes a layer of silty alluvial material flocculated by the high concentration of soluble salts; and Keaau clay, saline (0-2 % slopes), a poorly drained soil on coastal plains on Oahu, developed in alluvium deposited over reef limestone or consolidated coral sand, occurring in depressions adjacent to the ocean or in limestone pockets where seepage water evaporates, strongly affected by salts, the surface structure is platy or vesicular, and under natural conditions this soil is either idle or used for pasture (Foote et al. 1972: 49, 65, & 73).

The climate of the project area, similar to other windward coastal areas of O`ahu, consists of 40-50 inches of annual rainfall with the highest rainfall occurring between November and March with the lowest in June and July. Frequent showers occur with the most during the early morning and evening periods. The prevailing wind is from the northeast and ranges between 4 to 24 miles per hour during trade-wind conditions. The average temperatures range between 65^{o} F to 85^{o} F; they are lower during December through March and higher during May through October.

HISTORICAL BACKGROUND

The earliest accounts of the lands of Ko`olaupoko appear in legends about Hawaiian gods and demi-gods. Hiiaka, Pele’s younger sister; Hina, who left earth to dwell on the moon; and Kane, one of the four principal Hawaiian gods are all associated with the district (Pukui 1926). Kane was the Hawaiian god of creation and ancestor to both chiefs and commoners (Westervelt 1907:82 in Devaney et al.1976:1). The land of Waikane bears his name because he first dug for water there (Pukui 1926). However, his name does not appear to be associated with the name of the subject *ahupua`a.* Kane`ohe, the name literally means “bamboo husband.” According to an oral tradition, a woman when asked about her husband by another compared his cruelty to the cutting edge of a bamboo knife (Pukui et al. 1974:85; Sterling and Summers 1978:205).

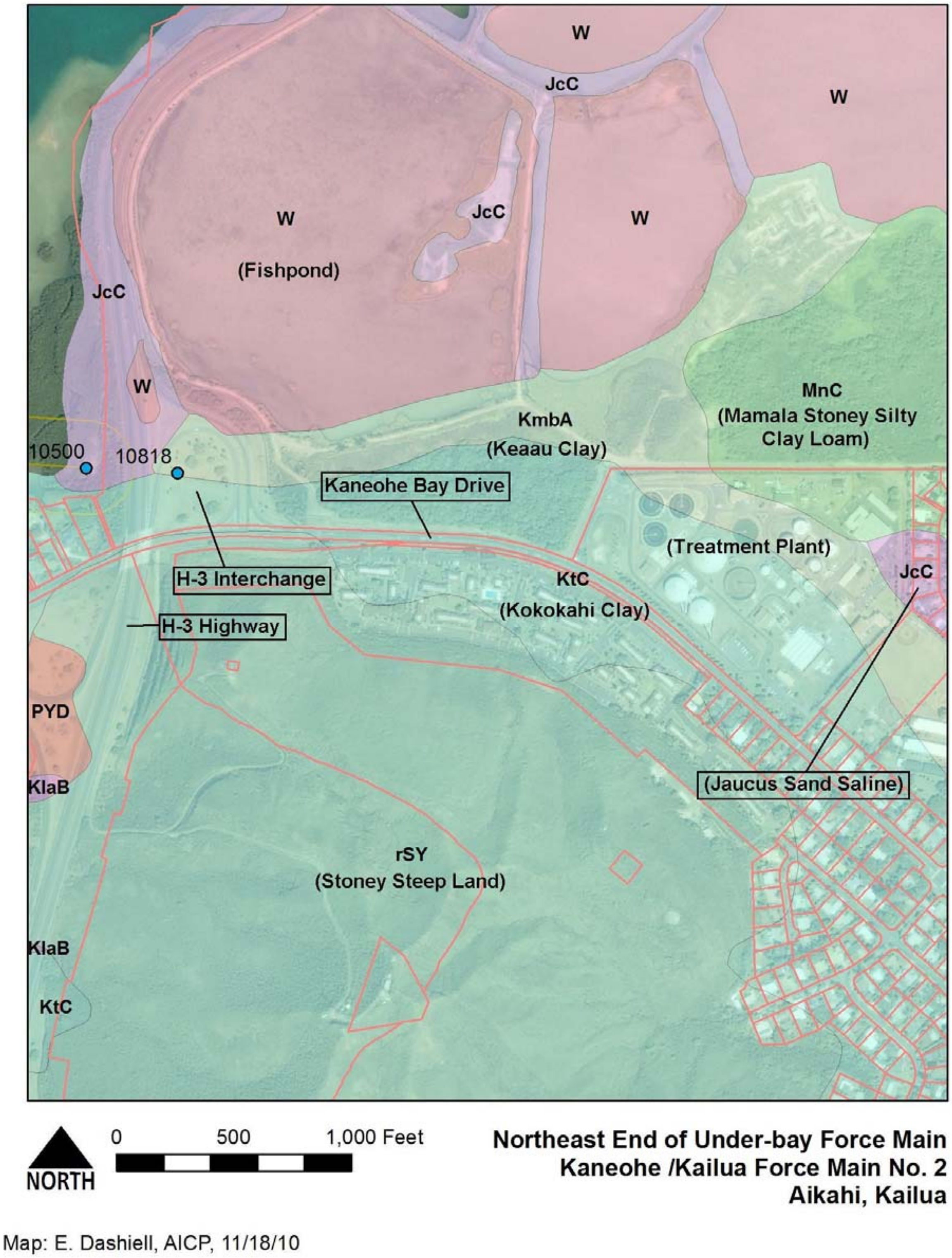

Figure 8. Soils in the Aikahi End of the Project Area

Hawaiian gods are not only found in legends, but are incorporated into various aspects of daily life. Prayers or *oli* (chants) were offered prior to each new event to smooth the way and ensure success for a new undertaking and to give thanks for divine aid upon the successful completion of an event. The *kapu* of the gods pertinent for each activity, ie. fishing, planting, and gathering, were applied with appropriate behavior to suit the requirements of the occasion. The essence of such customs or protocols can be interpreted as ways in which the Hawaiians sensitized themselves to their environment (Devaney et al. 1976:1-2).

For the early Polynesian arrivals with a horticultural and marine exploitation subsistence base, windward O`ahu, particularly Ko`olaupoko, was an ideal location for the establishment of permanent settlements. The lagoonal marine environment of Kane`ohe Bay probably served to remind these early settlers of their home islands. Thus, archaeologically, the earliest available radiocarbon dates have been obtained from habitation sites in Windward O`ahu. Kawainui Marsh in Kailua and Bellows in Waimanalo produced dates ranging between A.D. 200 to 600.

The windward region of Ko`olaupoko has long been considered the "bread basket" of O`ahu and highly favored with well-watered agricultural lands and verdant fishing grounds. Many prehistoric personages are said to have resided there including La`amaikahiki who upon voyaging from Tahiti landed and resided in a place formerly known as Wai-hau-palua, which over time came to be known as Waikalua (Sterling and Summers 1978:209). During the early historic times, many of the ruling chiefs favored Kane`ohe as their place of residence. Kahahana the ruler of O`ahu sometimes resided there. Kahekili after defeating Kahahana lived in Kailua, Kane`ohe, and He`eia. In 1795, Kamehameha I when apportioning the conquered O`ahu lands to his high ranking supporters, he retained Kane`ohe *ahupua`a* for himself. Later his sons inherited much of Kane`ohe, Kahalu`u, and Kualoa. During the Mahele, Queen Kalama, the wife of Kamehameha III was awarded 9,500 acres of Kane`ohe *ahupua`a* as well as large land tracts in Kailua, including LCA 4452 which incorporated the Aikahi area. Over 40 Land Commission Awards occurred in the vicinity of the Waikalua end of the project area, with the majority described as agricultural lots, either *lo`i kalo; mo`o aina,* narrow strips of land, or *kula* for dryland agriculture. The LCA data on Registered Map 1897 has been previously compiled and described (Cordy 1977).

By the late eighteenth and early nineteenth centuries a population range between 14,600 and 18,400 persons for the nine *ahupua`a* with frontage on Kane`ohe Bay could be estimated (Devaney et al. 1976:7). Due to pestilence and also the movement of people to the developing urban centers in and around Honolulu in leeward O`ahu had depopulated the Kane`ohe Bay area so that by 1831-1832 the population had decreased to 3,019 persons. Kane'ohe *ahupua`a* had the most persons at 1,159 which was twice as many as the next highest number in neighboring He`eia (Devaney et al. 1976:8-9). The population continued to decline to its lowest point in 1872 with 2,082 for all of Ko`olaupoko. By 1896, however, it had increased to a total of 2,753 persons which was the result of imported labor, most likely Chinese who were cultivating rice and operating the fishponds in Kane`ohe Bay (Devaney et al. 1976:11). Following WWII, Kane`ohe became a popular residential area based on its proximity to downtown Honolulu, especially following the completion of the Pali and Wilson Tunnels. Between 1940 and 1960 the population of Kane`ohe more than quadrupled from 5,387 to 29,622 and by 1980 had reached 47,335 (Devaney et al. 1976:13 and Kane`ohe Bay Master Plan 1992:5).

The Polynesia settlers of the Kane`ohe area had extensively cultivated wetland taro, making full use of the well watered lands. During the early to mid-historic times following abandonment of many of these areas by the indigenous population, the Chinese immigrant farmers took up rice and Chinese taro production in the irrigated former taro fields. In the 1860s, the commercial cultivation of sugar cane commenced with a mill in Kualoa. By 1880, three more sugar companies had emerged in Kahalu`u, He`eia, and Kane`ohe. In 1880, the plantation in Kaneohe reported 7,000 acres available for cultivation. The commercial cultivation of sugar cane was short-lived because it was never as successful as in other parts of the island due to the limited availability of arable level lands. By 1885, the plantations had ceased operations. The commercial cultivation of rice did not occur in earnest until the decline of sugar, and in 1880 the first Chinese rice company started in Waihe`e area. The Kane`ohe Rice Mill was built around 1892-1893 in the Waikalua area (Devaney et al. 1976:49-51). Another commercial crop, pineapple, was also grown in the Ko`olaupoko region starting around 1910 and continuing on until the mid 1920s. Portions of Ko`okaupoko, especially Kane`ohe was also used for cattle grazing and ranching starting in the mid-1840s. Kane`ohe Ranch at one time operated 12,000 acres of ranch land with 2000 head of cattle. Ranching continued into the early 1970s. All of Mokapu Peninsula, now occupied by the Kane`ohe Marine Corp Base Hawaii, was at one time a grazing area (Devaney et al. 1976:70-74).

The compounded effects of these large scale commercial ventures had deleterious effects upon the land, the ocean, and the general environment of the Kane`ohe Bay region. The commercial agricultural endeavors altered expansive land areas contributing to the silting in of Kane`ohe Bay as well as diverting the natural freshwater sources. The ranching activities cleared cover vegetation from many areas and denuded the lands thereby adding to the erosion and silting in of Kane`ohe Bay. The rapid population growth following World War II soon exceeded the capacities of the available infrastructure, most notably the waste water treatment systems which became the major factor in the pollution of Kane`ohe Bay.

SUMMARY OF PREVIOUS ARCHAEOLOGY

A search for previous archaeological reports was conducted at the State Historic Preservation Division Library in Kapolei and the Pacific Collection of Hamilton Library at the University of Hawaii at Manoa. More reports were available for the Waikalua end of the project area than for the Aikahi end.

The two principal terrestrial areas associated with the emergence of the force main from the sea floor and the land-based connection to the existing sewage facilities occur on both ends of the proposed under-bay transmission line. The two areas are Waikalua on the western end and Aikahi located on the western half of the isthmus of Mokapu Peninsula. The principal archaeological elements within the proposed project area consist of complexes of traditional Hawaiian fishponds situated along the shoreline of southeastern Kane`ohe Bay connecting both of these areas. One recorded site, Waikalua Loko (SIHP Site 50-80-10-349), a fishpond occurs within the project area boundaries at the Waikalua end (see Fig. 3). Appendix A of this report includes excerpts from the Hawaiian Fishpond Study (Murabayashi et al. 1989) regarding Waikalua Loko. The only other recorded site that occurs near the project area is Nu`upia fishpond (SIHP Site 50-80- 11-1002) located within the boundaries of the Kane`ohe Marine Corp Base Hawaii.

Four principal references can be identified in the archaeological literature for Kane'ohe. The earliest is J. Gilbert McAllister's *Archeology of Oahu* published by the Bishop Museum in 1933, consisting of an island-wide inventory of archaeological sites. A compilation of supplemental data and updates to McAllister's inventory were subsequently completed by Elspeth P. Sterling and Catherine C. Summers and published by Bishop Museum in 1978 as *Sites of Oahu*. In 1976, under contract to the U.S. Army Corps of Engineers, the Bishop Museum produced *Kane`ohe: A History of Change (1778-1950)* by Dennis M. Devaney, Marion Kelly, Polly Jae Lee, and Lee S. Motteler. In 1989 a comprehensive inventory of extant fishponds on three of the main islands, the *Hawaiian Fishpond Study: Islands of O`ahu, Moloka`i, and Hawai`i,* was produced under contract to the State of Hawaii Coastal Zone Management Program by DHM Planners, Inc. and The Applied Research Group of the Bishop Museum. In addition to the foregoing reports, a number of more recent archaeological studies, accompanied by pertinent historical and land use investigations have addressed more specified project localities along the coast as well as adjacent inland areas. The following section summarizes salient elements of these reports.

Kane'ohe Bay And Vicinity

Among the types of sites recorded by McAllister were *heiau*, shrines, villages, agricultural sites, burials, and fishponds. Pertinent to the current project, the following provides a review of the fishpond complexes along the shoreline of Kane'ohe Bay within the *ahupua'a* of Kane'ohe as observed by McAllister during the 1920s and 30s. McAllister identified roughly 16 fishponds in the *ahupua'a* of Kane'ohe. Three of these ponds; Waikalua-loko and Waikalua, sometimes referred to as Waikalua-waho (listed together as Site 349); and Keana (Site 350); occur in the southwestern portion of the current project area (Figure 1). Within the *ahupua'a* of Kane'ohe, along the coastline northwest of the project area, McAllister's sites include Kalokohanahou fishpond, Site 343 (see Fig. 1), which is reported to have covered 7 acres (McAllister 1933:177). "According to Bell, this is not the old name, but the one used by Parker when he rebuilt the pond. The walls are but a few feet wide, loosely built of lava stones through which the water seeps. A small island occupies a portion of the wall. There were two watch-houses and no outlet gates (McAllister 1933:177). In Sterling and Summers (1978:208), the old name of this pond is given as Kohanahou. Devaney et al (1976:146) report that Kalokohanahou pond was filled for housing in 1947 and became Kahanahou Circle.

Near the mouth of Kea`ahala Stream, was Kanohuluiwi fishpond, Site 344, (see Fig.1) covering an area of 2.5 acres. "The name was given me by John Bell. The pond is small, with narrow lava-rock walls, and covers and area of 2.5 acres. It is apparently still in use. On one of the old maps in the land office there are two adjacent ponds of about the same size." (McAllister 1933:178). Kanohuluiwi pond in 1982 is described as being well-preserved with a narrow lava-rock wall, and covering an area of 2.7 acres (Devaney et al 1982:145). The *Hawaiian Fishpond Study* (Riford and Murabayashi, et al. 1989: IV-27) gave this pond an excellent rating, but also described portions of the original pond as being filled in.

About 500 meters east of Kanohuluiwi pond was Punaluu pond, Site 345 (see Fig. 1), with an enclosing wall about 1600 feet in length and covering an area of 12.5 acres (McAllister 1933:178). Sterling and Summers (1978:208) note that this pond had been filled. Devaney et al (1976:147) state that Punaluu pond was filled for housing between 1946 and 1948 and became Mahalani Circle.

Within the current project area, between the effluence of Kane’ohe and Kawa Streams and adjacent to the Kane’ohe sewage disposal facility, McAllister recorded three fishponds. Waikalua loko fishpond, Site 349 (see Fig. 1), is located immediately northeast of the facility. The pond wall was 1420 feet long, built of water worn basalt 3 to 4 feet in height and was somewhat wider than 4 feet. The pond covered an area of 11 acres (McAllister 1933:178). Waikalua loko fishpond was rebuilt in the early 1930’s (Devaney et al 1976:147). On the Kailua side, immediately adjacent to Waikalua loko fishpond, were two smaller ponds, Waikalua and Keana fishponds Site 350 (see Fig. 1). “The pond in use is said to be Keana with an area of 3.5 acres. According to Bell, the name of the other is Kalokohanahou. (see Site 343.) Its wall is broken. Both were built of waterworn basalt. The dirt-filled wall of Keana is wide enough for trees to grow on it” (McAllister 1933:178-179). According to Devaney et al (1976:147) these two ponds are named Keana and Waikaluawaho and were formerly one pond. In 1982 a remnant of Waikaluawaho remained at the estuary of Kawa Stream, and Keana pond was artificially filled in the 1950’s (Devaney et al 1976:147). McAllister described three additional sites previously located in Waikalua within proximity to the present project area which were no longer in evidence in 1930. These sites include Site 346; a deep ditch dividing the lands of Punaluu and Waikalua; Site 347, Kalaoa heiau; and Site 348 the former location of the houses of Laamaikahiki (McAllister 1933:178). McAllister additionally describes a spring in proximity to Keana Fishpond, Site 353, “A spring on the land known as Keana (now Kokokahi), called Kinikailua-Manokaneohe, as it is said that the people from both Kailua and Kaneohe died in great numbers from drinking its waters” (McAllister 1933:179). Mary Kawena Pukui wrote; “Kini Kailua, mano Kane`ohe. *Forty thousand in Kailua, four thousand in Kane`ohe.* A great number. Said by a woman named Kawaiho`olana whose grandson was ruthlessly murdered by someone from either Kailua or Kane`ohe. She declared that this many would perish by sorcery to avenge him. Another version credits Keohokauouli, a *kahuna* in the time of Kamehameha, for this saying. He suggested sorcery as a means of destroying the conqueror’s O`ahu enemies” (1983:193 Proverb 1801).

Along the shoreline of Kane’ohe Bay, to the northeast of Waikalua-loko and Keana fishponds and between where the proposed force main pipeline reaches land, McAllister identified six fishponds. Site 351 consists of three adjacent ponds located along the shoreline of the lands of Mikiola and Mahinui in Kane’ohe (see Fig. 1). “The two end ponds were probably built first, the middle pond being added later so as to take advantage of the walls of the other two. The pond on the east is known as Mahinui and that on the west as Mikiola. The name of the middle pond is

Kaluoa, according to John Bell, but appears as Kapuu on a map in the Bishop Estate office. The wall of Mikiola is broken" (McAllister 1933:179). According to Sterling and Summers (1978:210), Mikiola had been filled and Mahinui had been partially filled. Devaney et al (1976:147) report that Mikiola, Kaluoa, and Mahinui ponds were all filled between 1946 and 1948 where Mikiola Drive is today.

Keaalau pond, Site 361, covered an area of three acres adjacent to the lands of Keaalau (see Fig. 1). Keaalua pond was filled for housing between 1946 and 1948 where Nohokai Place was constructed (Devaney et al 1976:147). Hanalua fishpond, Site 362, "… takes its name from adjacent land. It is a small pond a few acres in size and marks off an inlet" (McAllister 1933:182). Hanalua pond was artificially filled between ca 1946 and 1948 and is part of the Kane'ohe Yacht Club (Devaney et al 1976:147). Papaa fishpond, Site 363, is a small pond named for the lands to which it is adjacent (McAllister 1933:182). Devaney et al (1976:147) report that the wall of Papaa pond was cut in the 1940's and that vegetation covers the remnant of the pond (see Fig.1).

Occupying the isthmus of Mokapu Peninsula, adjacent to the eastern corridor of the project area, McAllister identified Site 364, a complex of three large adjoining fishponds (see Fig. 1). These three ponds separate the isthmus portion of Mokapu Peninsula from the Kane'ohe Marine Corps Air Station which occupies all of the northern part of the peninsula. McAllister describes the ponds as; "Halekou, Kaluapuhi, and Nu'upia, three adjoining fishponds on Mokapu Peninsula. Kaluapuhi on the east covers 24 acres and is connected with Kailua Bay by one outlet (*makaha*), by means of which it can be flooded at high tide. It is separated from Nu'upia by a wall. Halekou of 92 acres and Nu'upia of 215 acres, are on the west, separated from Kaneohe Bay by a long wall" (McAllister 1933:184). Sterling and Summers (1978:213-214) designate Kaluapuhi pond as Site 364-A, Nu'upia Pond as Site 364-B, and Halekou Pond as Site 364-C. Although considerably decreased in size than as described by McAllister, these ponds are among those still extant in Kane'ohe Bay in 1976 and described as: "Nu'upia, modified in the 1940's and recently, now 180 acres; Kaluapuhi, originally included Nu'upia with 297 acres, now 14 acres; and Halekou, extensively filled in the 1940's, now 36 acres in parts" (Devaney et al 1976:147).

Mokapu Peninsula

Native Hawaiian interments located in the sand dunes along the northern and eastern shoreline of Mokapu Peninsula have been the focus of a number of archaeological investigations. These burial complexes occurred in portions of both Kane'ohe and Heeia *ahupua'a.* A comprehensive analysis of human skeletal remains and related artifacts, along with the history and context of the archaeological excavations which recovered these remains are provided in an *Inventory of Human Skeletal Remains from Mokapu Peninsula, Ko'olaupoko District, Kane'ohe and He'eia Ahupua'a, Oahu Island, Hawaii* prepared in 1994, by Sara Collins, Toni Han, and Lisa Armstrong of the Anthropology Department of the Bishop Museum. The inventory spans the period between 1915 and 1993 at which time a total of 1,125 burials had been documented (Collins et al 1994: iv,v). Prior to formal archaeological investigations, between 1915 and 1933 a number of human remains from the Mokapu sand dunes were collected and accessioned by staff or associates of the Bishop Museum. The first formal excavations were carried out in the He'eia Dunes by Kenneth Emory, Bishop Museum ethnologist, in 1938 (Emory and Sinoto 1961). Following an inadvertent discovery, the contents of 121 burials were recovered and accessioned (Collins et al 1994:14, 17). The 1994 inventory found 119 individuals represented in the remains from this accession (Collins et al 1994:18). No maps exist which locate the burials found during this exploratory excavation. The findings of this first exploratory excavation led to the planning of a subsequent, large-scale, systematic excavation.

Between 1938 and 1940 three extensive site areas were excavated by Kenneth Emory of the Bishop Museum, and Gordon Bowles, assistant professor of anthropology at the University of Hawaii (see Fig. 1). Bowles designated site areas 1, 2, and 3; area 1 was located in the western He'eia dune and site areas 2 and 3 were located in the central and western, Heleloa dune areas of the peninsula (Figure 4 from Collins: 21). Site 1 or H Site yielded a total of 440 burials. Collins et al (1994:19) found a minimum 662 individuals represented in the Site H collection. Site 2 or C Site was excavated on the central ridge of Heleloa. Boweles reported 69 burials from the C site excavations and Collins found a minimum number of 76 individuals represented in the C Site burials (Collins et al 1994:27). Site 3 or N Site was located on the eastern ridge of Heleloa dune. Collins' inventory (1994:27) reports a minimum number of 108 individuals represented from the excavations of 74 burials at Site 3 or N Site. In 1957, Robert Bowen, a graduate student in anthropology at the University of Hawaii, conducted salvage excavations at Site 2 or C Site on the central Heleloa ridge and Site 3 or N Site on the eastern ridge of Heleloa dune. Bowen (1974) reported at least 87 burials from Site C and at least 21 burials from Site N. Collins found a minimum of 163 individuals represented the C Site burials and a minimum of 23 individuals from the N Site burials (Collins et al. 1994:33). Between 1950 and 1969 a number of inadvertent discoveries were accessioned by the Bishop Museum. In 1975, archaeological salvage excavations were undertaken by the staff of the Bishop Museum for the Kailua Effluent Force

Main project which included a corridor 7,802 feet long on the eastern shoreline of Mokapu Peninsula. The KEFM site (Bishop Museum Site number 50-Oa-G5-67) included 94 burials. Both pre-contact and historic period burials were reported in three distinct clusters (Davis et al. 1976). A minimum of 108 individuals were represented in the Collins inventory of the KEFM remains (Collins et al 1994:39). Between 1970 and 1993 a number of inadvertent burials were accessioned by the Bishop Museum (Collins et al. 1994:42, 43).

Attempts to date the interments from Mokapu peninsula, through radio-carbon analysis of associated organic materials or through the analysis of associated funerary artifacts, appear to be severely limited. A single radiocarbon date was obtained from carbon material associated with a child's skeleton (H132) which was excavated in 1939. This material provided a date of 75 +/- 75 years (Sterling and Summers 1978:217). When this sample was tested remains unclear. Volcanic glass flakes from both burial and occupational contexts from the KEFM site were dated, ranging from A.D. 1270+/-34 to A.D. 1694+/- 68 years (Collins et al. 1994:39). These dates have been cited in numerous subsequent reports (Athens 1985; Barrera 1982; Cordy 1984; Charvet-Pond and Rosendahl 1992), and appear to be the only absolute dates derived from the Mokapu Peninsula burials

A comprehensive inventory of funerary objects associated with the Mokapu burials, consisting of both traditional and historic period artifacts, is provided in Collins (1994:76-104). Assemblages containing buttons and ivory, bone, and glass beads were recovered from the KEFM project (Collins et al. 1994:85-96) Similar artifacts are represented in assemblages associated with the Keeaumoku Wal-Mart burial complex and are believed to represent the period between ca 1850 and ca 1880 (Titchenal 2003). The human remains from Mokapu Peninsula housed at the Bishop Museum have provided a data base of Hawaiian osteology for a number of research publications including Cleghorn 1987; Douglas 1987 and 1991; Han et al. 1986; Howells 1973a, 1973b, 1989; Keene 1974, 1986; Kirch 1985; Pietrusewsky 1970, 1985, 1989; Schendel 1980; Saki 1974, 1975; Suzuki 1987a, 1987b, 1993; Turner 1989a, 1989b; Wright 1992.

Inland Watersheds Of Kane'ohe *Ahupua'a*

A number of comprehensive archaeological investigations were undertaken in the inland areas of Kane'ohe *ahupua'a* between the mid-1970's and the mid-1980's. Among these were reconnaissance level survey and salvage excavations undertaken in the Kamo'oali'i and Kane'ohe Stream drainage area by Bishop Museum (McCoy et al. 1976 & Rosendahl 1976) in association with the Kailua-Kane'ohe Flood Control Project. Within the current project area, this survey included the immediate banks of Kane'ohe Stream. Below the confluence of Kuou and Kamo'oali Streams, the immediate banks of Kane'ohe Stream had all undergone development and no evidence of previously unrecorded sites were found (Rosendahl 1976).

Research undertaken by the Bishop Museum in the early 1970's, in association with the Kane'ohe Bay Urban Water Resource Study conducted by the U.S. Army Corps of Engineers, resulted in the publication of *Kane'ohe: a History of Change (1778-1950)* (Devaney et al. 1976). This document provides a comprehensive history of the *ahupua'a* of Kane'ohe and includes sections on agriculture, water and forest resources, and biology and marine resources. Of particular interest is a section describing *Walled Fishponds of Kane'ohe Bay* (Devaney et al 1976:139-159) which provides some historical background along with early photographs (1887) of the ponds within the current project area including Waikalua-loko (Devaney et al 1976: 145-148).

Also, in support of the Kane'ohe Bay Urban Water Resources Study, the Environmental Branch of the U.S. Army Corps of Engineers (Cordy 1977) provided a report delineating the problems, and suggesting solutions, related to long term cultural resources planning in Kane'ohe Bay. Among the elements of this report, pertinent to the current project area, is a model predicting the distribution of cultural resources by habitat and *ahupua'a.* Within the project area Cordy suggests the potential for traditional housing, burials, and heiau along the alluvial shoreline; irrigated agriculture along the stream flats; and the possibility of dry agriculture, housing, burials, and heiau along the slopes adjacent to stream flats (Cordy 1977:6-7). Cordy additionally suggests that lands in and adjoining the current project area are among those areas that have already been destroyed or greatly altered (1977:8). The report also provides a detailed map of *mahele*-era land commission awards in the area of the mouths of Kawa and Kane'ohe Streams and adjacent to Waikalua-loko (Cordy 1977: 50).

In 1984, archaeological and historical investigations were undertaken by the Department of Anthropology of the Bishop Museum for the proposed Interstate Highway H-3 interchange resulting in the report *Five Upland 'Ili: Archaeological and Historical Investigations in the Kane'ohe Interchange, Interstate Highway H-3, Island of O'ahu* (Allen et al. 1987). Prior to this undertaking, a number of archaeological investigations focused on the upland drainages of Kane'ohe *ahupua'a,* in the vicinity of what is now the Luluku Interchange of the H-3 Highway. In 1972, reconnaissance survey and inventory resulted in the recording of historic period habitation and agricultural sites, rock alignments, ditches, and terrace complexes (McCoy and

Sinoto 1976, Rosendahl ed). In 1976, a six day reconnaissance for the proposed H-3 alignment recorded four sites (Cleghorn and Rogers-Jordane 1976). Several of these sites were re-examined the following year (Dye 1977). A survey conducted for an alternative H-3 alignment by the Bishop Museum resulted in the recording of 12 additional sites (Streck 1982). . Allen et al (1987:174-179) describe 16 radio-carbon dates obtained from various contexts from the five upland *'ili.* A number of these dates however are questionable. A problem encountered by two researchers including Klein et al. (1982) and Schilt (1984) is that two laboratories frequently assign differing dates to the same sample. "A prime case in point is unfortunately provided by the important, earliest pondfield samples at Site G5-85: the tree samples from Feature 35, Trench 3 Layer VIII. While the two dates processed by Beta Analytic overlap, suggesting a range between A.D. 440 and A.D. 620, the same sample processed by Teledyne has been assigned an A.D. 1405-present range (Klein et al. 1982). The same sample that yielded the Teledyne and Beta Analytics (b16266) dates had been carefully divided between the two laboratories to avoid biasing either sample" (Allen et al. 1987:174). A single hydration date was obtained from a non-diagnostic fragment of volcanic glass from Site G5-85. This sample yielded a date of A.D. 1285 +/- 150 years (Allen et al. 1987:179). Based on these dates, Allen et al. (1987:179) provide the following conclusions:

> 1. At Site G5-85, dryland agriculture began in the Feature 1 to 10 terrace set by the 13th century, followed almost immediately by pondfield agriculture in both Features 4 and 9; pondfield cultivation probably continued into the 18th or early 19th century. In the dowslope terraces (Features 30 to 38), pondfield agriculture spanned the 5th through 16th or 17th centuries at a minimum.
>
> 2. Only one date, from Layer II, is available for Site G5-86. Dryland cultivation probably took place in the 11th century, slightly before dryland agriculture is indicated at Site G5-85, downslope, but contemporaneously with pondfield agriculture in the lower terraces (Site G5-85 Features 30 to 38).
>
> 3. The Feature 9 platform was probably in use between the 13th and 17th centuries at a minimum. No volcanic or C-14 dating was possible at the Feature 37 platform.
>
> Layers I and II at the localities tested unfortunately produced inadequate material for dating; the terminal dates for field use thus remain undocumented. A 19th-century date is probably accurate in most cases.

An additional study in the upper drainages of Kane'ohe Stream provided a sediment coring record from Kapunahala Marsh (Athens and Ward 1996). The marsh is drained by Kapunahala Stream which eventually empties into Kane'ohe Stream. A single sediment core was recovered in June 1994 within the approximate alignment of a proposed road within Kapunahala Marsh. Six radiocarbon samples were processed from intervals of the core. The entire sequence covers roughly the last 4,600 to 4,800 years (Athens and Ward 1996:8).

> The pollen and charcoal particle records indicate prehistoric land use within the Kapunahala watershed by about A.D. 1400 to 1500 (450 to 550 years B.P.). At the next earlier sampling interval, dating to about A.D. 950 (1000 years B.P.) there is no clear evidence for sustained Polynesian settlement or agriculture. Although the stratigraphic unconformity here prevents a determination of exactly when this might have occurred at the Kapunahala location, results from the nearby Maunawili core indicate a date of A.D. 1200 for the onset of interior burning and forest decline, which is also reasonable in regard to other archaeological evidence (Athens and Ward 1996:30).

Investigations In The Vicinity Of The Project Area

A number of archaeological investigations were undertaken in the vicinities of both the Waikalua and Aikahi ends of the current project corridor. This section summarizes pertinent projects at each end of the project area. The locations of these studies are depicted on Figure 9.

Waikalua

In 1986, Bishop Museum conducted archaeological surface survey followed by salvage excavations at Site 50-Oa-G5-101 in the proposed Nani Pua Gardens II subdivision (Kurashina et al. 1986 & Clark and Riford 1986). The 1.7 acre project area is located adjacent to the northwestern corner of the Bay View Golf Course portion of the current project area. The project area is bordered on the north and east by Kane'ohe Stream and is situated on a stream terrace about 2 m higher in elevation than the flood plain along Kane'ohe Stream. The discovery and preliminary investigation of Site 50-Oa-G5-101 was carried out by Kurashina et al. (1986). These preliminary investigations included a systematic surface collection which yielded 187 lithic specimens and two porcelain fragments. Five test excavations were also carried out. Charcoal collected from a pit feature in test excavation T5-5 provided a radiocarbon date of AD 1070-1390 and a piece of volcanic glass produced an estimated date range of AD 1494-1634 (Kurashina et al 1986). During this survey several other sites were recorded in areas immediately north and east of Site 50-Oa-G5-101. These included two lithic scatters (Site 50-Oa-G5-100); a former rice field and taro field with a stone retaining wall (Site 50-Oa-G5-103); a historic house foundation (Site 50-Oa-G5-104); two modern stone platforms, an Italian prisoner of war camp, and the Kane'ohe rice mill (Kurashina et al. 1986). Following these preliminary investigations additional salvage excavations were undertaken by Bishop Museum staff in which backhoe trenches and

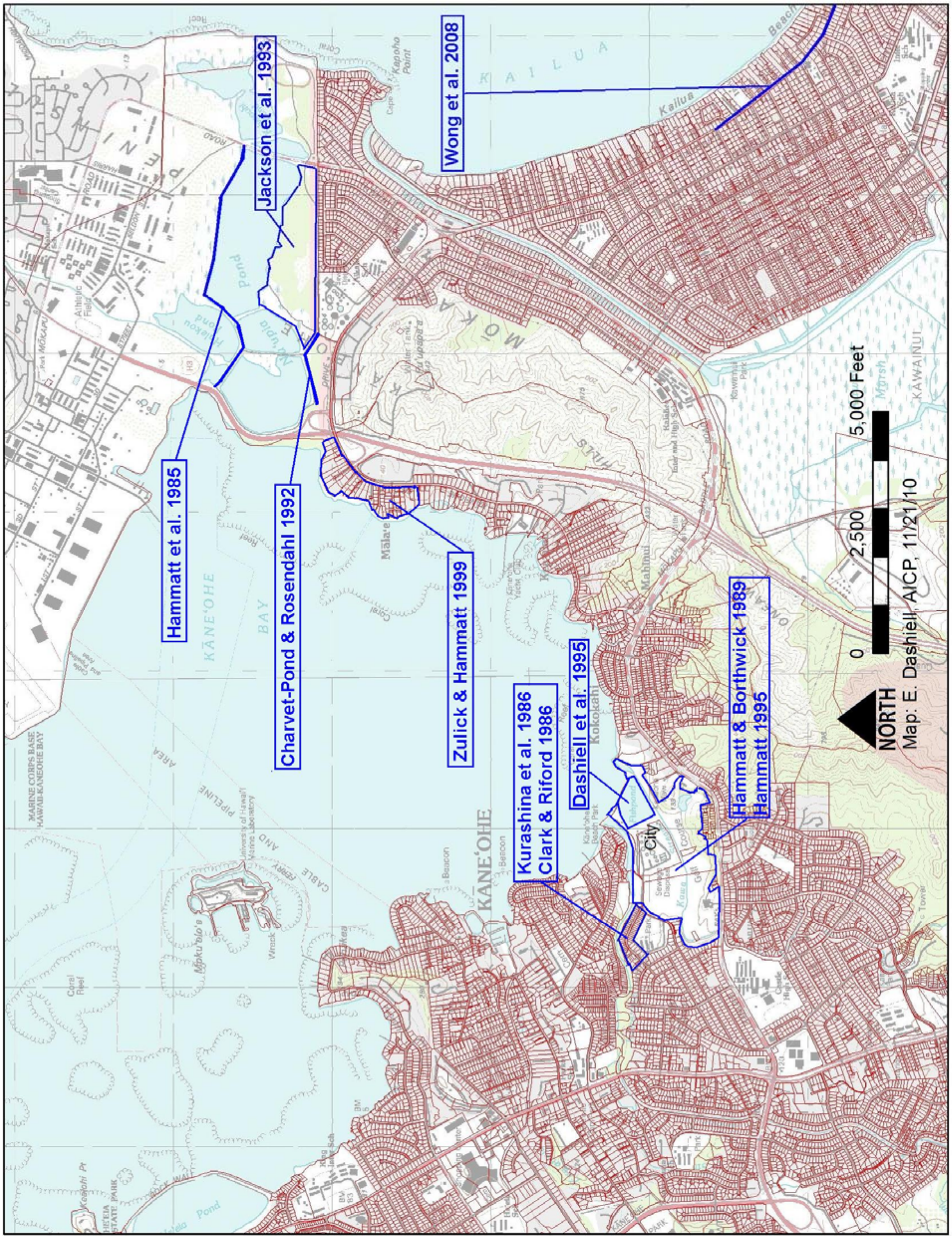

Figure 9. Locations of Previous Investigations in the Vicinity of the Current Project Area

controlled excavations yielded over 12,000 portable artifacts, and evidence of large pole houses with *in situ* burials below habitation floors (Clark and Riford 1986).

A total of 13 backhoe trenches were excavated in the project area and based on the cultural deposits and features revealed in the trench profiles, controlled excavations were carried out, adjacent to trenches in three sample areas. The discovery of burial features 9a and 9b in the Trench 1 profile led to the excavation of five addition burial search test pits (Clark and Riford 1986:8-11).

Trench and test excavations revealed an intact cultural layer (Layer II) 4 to 30 cm in thickness extending across most of the project parcel. Three stratigraphic units were present in the test excavations. Layer I, averaging about 50 cm in thickness, consisted of bulldozed clay loams and silty clay containing some cultural materials. Layer II consisted of dark brown, clay loam constituting a buried A horizon containing cultural materials and features. The upper proveniences of Layer II had in most cases been disturbed by bulldozing. Layer II averaged about 20 cm in thickness and contained a wide range of cultural materials and numerous features extending into the underlying Layer III soils. Layer III was composed of sterile, dark reddish brown silty clay (Clark and Riford 1986:14-22).

A total of 28 archaeological features were recorded in the backhoe trench profiles including 18 postholes, 5 pit features, a burned soil area, and a human burial, Feature 9a which was later excavated as part of sample area 9. Artifacts recovered from the backhoe trench backdirt piles included 1,245 diagnostic basalt flakes, 16 basalt flakes with polished facets, 16 adz performs and 16 possible performs, 30 modified flakes, 6 awls, 1 chisel, 1 grindstone fragment, 1 anvil, 2 hammerstones, 6 diagnostic volcanic glass flakes, a square nail and a ceramic mug handle (Clark and Riford 1986:29).

Ten additional features were recorded in the three sample area excavations. These included five postholes, a charcoal lens, two hearths, and two human burials. Artifacts recovered from the sample excavations included 64 diagnostic basalt flakes, 3 adz performs, 1 awl, and 1 modified flake (Clark and Riford 1986:45). Eight bone artifacts were also recovered from the trench and sample excavations including fragments of three bird bone tattoo needles and a tattoo needle brace, a fragment of a mammal bone pick, a possible fish tooth ornament, and two unidentified mammal bone artifact fragments (Clark and Riford 1986:83).

A total of three radiocarbon assays were submitted from Site 50-Oa-G5-101 including one from Kurashina's preliminary investigation. The Kurashina et al (1986) sample (HRC #755) provided a date of A.D. 1070-1390. Clark and Riford submitted two charcoal samples. One (HRC # 823) returned a date of A.D. 1200-1405 and the other sample (HRC # 824) provided three possible dates; A.D. 1510-1950, A.D. 1510-1680, A.D. 1705-1810. Additionally the single volcanic glass age determination from preliminary investigations (Kurashina et al 1986) returned a date range of A.D. 1494-1634. Based on this data, Clark and Riford (1986:99) conclude that the duration of occupation for Site 50-Oa-G5-101 is estimated to be at least five centuries, from A.D. 1070 to 1634.

Aikahi

Several archaeological investigations have been undertaken in the vicinity of the eastern segment of the current project area corridor which extends eastward from the H-3 interchange to the existing Aikahi sewage disposal facility Archeological coring and testing were carried out in 1985 (Hammatt et al.) for a proposed predator control moat along the northern perimeter of Nu'upia pond. Eleven pipe core column samples were extracted and five test trenches were excavated. Additionally, several midden/lithic scatters were identified in the project area but were apparently not assigned site numbers. From the core samples, two organic strata were submitted for radio carbon dating but provide somewhat ambiguous data. One sample had insufficient datable content, the other yielded two dates: 4550+/- 50 B.P. 1010+/- 95 B.P. "The 3,000 radiocarbon year discrepancy between the two dates is resolved by rejecting the early date on the inorganic fraction" (Hammatt et al. 1985:41). The stratigraphic units in the sample cores showed gleyed calcareous fishpond sediments overlying marine sand. Hammatt et al (1985: i) concluded the pre-fishpond environment was a channel open to the ocean and separating Mokapu from the mainland. The man-made embayment of the water by fishpond construction caused greater variability in salinity. A "death bed assemblage" of clams found in test trenches is believed to be associated with this event.

In 1992, PHRI undertook archaeological monitoring of sewer line trench excavations in several areas on Mokapu Peninsula. Task Area 1 was a trench approximately 500 m in length, connecting four manholes along the southwest periphery of Nu'upia Pond (Charvet-Pond and Rosendahl 1992:22-23). This trench generally parallels the present project corridor east of the H-3 interchange and north of Kane'ohe Bay Drive. No cultural materials or features were observed. Soil deposits exposed in trench excavation included modern landfill, gleyed sandy clays, and basal sandy muck, and coralline substrata (Charvet-Pond and Rosendahl 1992:22).

In 1993, archaeological monitoring, reconnaissance, and test excavations were conducted by BioSystems Analysis, Inc. (Jackson et al. 1993) in the same general vicinity in a 120 acre tract lying between Nu'upia Pond and the Kailua Sewage Disposal Facility. The reconnaissance survey resulted in the discovery of six previously unknown sites (State of Hawaii Sites 50-80-11-4638 through 4643). Site 4638 is an irregularly shaped pavement of limestone cobbles measuring 3.75 m N/S by 2.5 m E/W with no observed associated artifacts. Site 4639 is a roughly rectangular pavement or foundation of small limestone and basalt cobbles, 6.5 m N/S by 6.0 m E/W, with no associated artifacts or midden. Site 4640 consisted of a medium density basalt debitage and tool scatter with historic material. Artifacts included unmodified basalt debitage, utilized basalt flakes, a basalt adze blank, and a basalt adze perform. Historic materials included and aqua glass bottle, clear glass fragments, a piece of lead shielding, lumber and corrugated tin. Two excavation units were placed at this site. Site 4641 is described as a limestone boulder alignment measuring 5.5m E/W by 2.0 m N/S situated 2m north of a berm oriented in the same direction. No associated artifacts or midden were observed. (Jackson et al. 1993:18-21).

Site 4642 is described as a low density basalt debitage and tool scatter with associated historic material. The site measures approximately 15.8 m E/W by 7.9 m N/S. Ten artifacts were collected within the site boundaries including six unmodified pieces of basalt debitage, one basalt core, one basalt notched flake, one basalt utilized flake, one net sinker blank. Surface finds in the vicinity of the site area included two pieces of basalt debitage, an *'ulu maika* perform, and an adze blank. Historic remains included a low concrete enclosure, a metal pipe, fence post and barbed wire, a metal framed structure, and a scattering of modern ceramic and glass (Jackson et al. 1993: 21). Site 4643 is a limestone alignment measuring 11 m N/S by 2.5 m E/W. No artifacts or midden were observed (Jackson et al. 1993:21).

Three marine shell samples, obtained from test trenches in the lowest stratigraphic layer were submitted for radiocarbon dating to reassess the date of the molluscan "death assemblage" in the ponds reported by Hammatt et al. (1985). The calibrated dates are: 1430 to 880 BC; 940 to 360 BC; and AD 250 to 750. "The radiocarbon dates suggest that the demise of shellfish in the current pond setting may have occurred as more than one event. These data can be interpreted to indicate period demise of shellfish over a span of some 2150 years" (Jackson et al. 1993:79).

An archaeological assessment was performed by Cultural Surveys Hawaii in 1999 within a residential tract in the Mala'e area along the west coast of the isthmus connecting Mokapu

Peninsula with Kane'ohe for a proposed sewer line. No cultural materials or features were observed (Zulick and Hammatt 1999).

> The entire project area is presently comprised of as many as 69 residential house lots, nearly all of which are occupied by existing housing, accompanied by attendant sub-surface infrastructure. Extensive grading and filling of house lots and access streets occurred during the construction of the sub-division, considerably altering the surface topography… The original coastline has been altered with the creation of private inlets for moorings, and the addition of a dredged channel running adjacent to the shoreline to provide small boat access to shoreline house lots. Additionally, portions of the shoreline within the project area are bordered by sea walls to control erosion, as well as to provide mooring for small boats. These alterations leave unclear the extent of the modification, either seaward or inland, to the original coastline (Zulick and Hammatt 1999:13).

An archaeological monitoring procedure for a sewerline reconstruction project was undertaken on Kalaheo Avenue between Kualamo`o Street and Kailua Road in Kailua *ahupua`a* beyond the current project area to the east. The monitoring report for the Kalaheo Avenue reconstructed sewer-line project was completed in 2008. A potential cultural layer was located and historic glass bottles were occasionally encountered. No burials were inadvertently discovered. AMS dating of deposit at 0.50-0.60 m below surface produced a date of A.D. 1650-1890. Monitoring was recommended for any future construction project in area (Wong et al. 2008).

Investigations Within The Current Project Area

With the exception of the Bishop Museum survey (Rosendahl 1976) which found no sites along Kane'ohe Stream within the project area, only one archaeological investigation has previously been undertaken in a 90 acre parcel incorporating the western, Waikalua end of the current project area (see Fig. 9). No investigations have been undertaken that incorporates the corridor adjacent to Kane'ohe Bay Drive at the eastern, Aikahi end of the project area.

Waikalua

In 1989, archaeological survey and assessment were undertaken within portions of a 90 acre parcel for the proposed expansion of the Bay View Golf Course (Hammatt and Borthwick 1989). This survey included all of the current western project area as well as peripheral areas outside of the current project boundaries. Survey coverage was focused on the unmodified pasture portion of the floodplain and adjacent wooded slopes predominately at the south end of the project area bordering Kane'ohe Bay Drive, and a small portion of floodplain and wooded slope north of Kane'ohe Stream. The survey included an examination of Waikalua-loko, Waikalua and Keana fishponds. The ponds were assessed for their state of preservation and the potential for associated features and sediment data. Subsurface testing of the 90 acre parcel consisted of a series of 8 backhoe trenches situated along a 600 foot north/south transect oriented perpendicular to Kawa Stream immediately west of the Kane'ohe Sewage Treatment Plant.

The only archaeological sites located during the survey were Waikalua-loko and Waikalua fishponds (Fig. 10). No sites or cultural materials were found on the floodplain which had been heavily modified by construction of the golf course, the sewage treatment plant, and the widespread dumping of soil over formerly irrigated fields No sites were located along the slope areas adjacent to the floodplain, much of which had been modified by recent residential development (Ibid. 1989:28).

Subsurface testing consisted of 8 trenches averaging 7.5m in length and 240 cm (water table) in depth positioned at 50 to 100 foot intervals along a 600 foot transect. No buried cultural materials or features were found in any of the trenches (Ibid. 1989:35). Soil profiles, similar in all trenches; exhibit three strata as follows: Stratum I, averaging 0-80 cmbs, consisted of modern mechanical fill described as dark grayish brown silt loam to sandy clay containing basalt and coral gravel with modern trash, plastic, golf balls, and bottle glass with an abrupt wavy boundary; Stratum IIA, averaging 80-120 cmbs was naturally deposited agricultural soil described as reddish brown, clay loam with fine strong angular blocky structure with clay and iron coatings between peds and pronounced iron stained root casts, with a clear wavy boundary. Stratum IIB, averaging 120-240 cmbs (to the water table), also consisted primarily of naturally deposited agricultural soil (Ibid. 1989:34) described as grayish blue, clay, with pronounced iron coatings on root casts. The extensive deposit overlying the pond field deposits consisting of imported fill containing historic and modern refuse led the researchers to conclude that expansive areas of the floodplain was filled during historic and modern periods to reclaim wetlands.

In addition to the negative findings of the survey and descriptions of the test trenching portion of the investigation, the report (Ibid. 1989: pp29, 31, 33) provides observations of Waikalua-loko and Waikalua ponds as they appeared in 1989 as follows:.

> …..Both Kane'ohe and Kawa Stream beds near the coast have been bermed for flood control with imported gravel fill and the outlets of these steams contain only recent alluvial deposits.
>
> The two extant fishponds on the property are Waikalua-loko and Waikalua Ponds. The third pond shown on the historic maps adjoining Waikalua Pond to the east – Keana Pond- was filled in during the 1950 (Devaney et al. 1976:147) and not a trace of its former outline survives. Each of the two remaining ponds is described as follows:

Figure 10. Aerial Overviews of Waikalua-loko; top to southeast; bottom to southwest, May 1989 (from Hawaiian Fishpond Study 1989: IV-73/74)

Waikalua-loko Pond

This pond which stands between the outlets of Kane'ohe and Kawa Streams is in some sources referred to as simply Waikalua Pond, but the name shown on the modern tax map is used in this report. The pond has a 2-4 foot high seawall which separates the interior from the reef. The wall is 2-4 feet high and 10-15 feet wide and the center is in sections, filled with sand and coral. The gates of the pond are mortared lava rock with wooden frame works and bridges.

The seawall is relatively clear of vegetation except at the east and towards Kawa Stream and is in portions somewhat jumbled by wave action on the seaward side. The wall measured to be 1520 feet long (McAllister 1933:178) but appears to have been shortened somewhat by the berming of the Kane'ohe Stream mouth at the northwestern end of the pond.

The waters of the pond are generally clear of vegetation except at the southeast end. The size estimates of the pond in various sources vary from 11 acres to 13 acres (Devaney et al. 1976 139,146) but this variation may be simple differences in calculation rather than actual changes in the pond through time. Review of the various historic maps showing the pond indicate that its size and placement of its seawall has remained the same in the last 100 years. Apparently the pond went through rebuilding in the early 1930s and McAllister reports that this work had just been completed (Ibid. 1933:133).

Besides fish rearing the pond has been used for raising oysters (Devaney et al. 1976:145). Cobb in his 1901 survey of fishponds for the U.S. Fish Commission listed Waikalua (loko Waikalua) Pond as one of 16 ponds in Kane'ohe Bay which were still in commercial production (Cobb 1902:748).

The historic maps show Kawa Stream entering the *mauka* side of Waikalua Pond. This stream in recent times has been diverted to its own channel which outlets at the eastern side of the pond.

Waikalua Pond

This pond borders Waikalua-loko on its eastern side. It has been referred to by other names such as Waikalua-waho or Waikalaa. A 1-2 foot high and 3-4 foot wide seawall survives on the east side of the present channel of Kawa Stream. The pond wall and interior are overgrown with mangrove and at present, there is no open water. The east and south sides are not clearly defined but a sewerline lies buried close to the periphery.

It appears from historic maps that Waikalua Pond never had an established source of fresh water as did Waikalua-loko although there was probably fresh water seepage. The pond in its original extent covered 3.5 acres and at one time connected to the now destroyed Keana Pond (Devaney et al 1976:147).

Following Hammatt and Borthwick's 1989 investigation, an archaeological monitoring and interim preservation plan for implementation during the proposed expansion of the Bay View Golf Course was completed in 1995. This plan addresses archaeological monitoring during construction activities and archaeological preservation of Waikalua-loko and Waikalua fishponds. Waikalua-loko is recommended to be actively preserved, restored, and maintained and Waikalua pond is recommended for passive preservation with no plans for future restoration or maintenance. Monitoring during construction was outside of the current project area and within the existing golf course area (Hammatt 1995).

A preservation plan revision subsequently prepared for Waikalua Loko (Dashiell et al. 1995) provided a number of additional observations and assessments of the pond as it appeared in 1995 (Fig. 11). The plan discussed the preservation mandate issued in conjunction with the Special Management Area Permit and proposes restoring the pond generally to the state of the 1930s conditions when a major reconstruction into the current configuration was undertaken (Dashiell 1995). Thus, the primary goal of the preservation plan was to preserve Waikalua-Loko Pond "in place, with no modifications except those which will serve to preserve or improve the conditions of the site as a functioning Hawaiian fishpond" (Dashiell et al. 1995:6). In addition to describing the results of surface assessment and providing suggestions for preservation, the report provides a detailed chronological history of the pond and consequent alterations through time. In 1995 the pond is described by Dashiell et al. (1995:1-3) as follows:

> At present, the pond has been significantly altered due to a reconstruction of the wall in 1930. Portions of the pond have been filled, about two feet of sediment has accumulated in the pond bottom and fresh water sources from the adjacent Kane'ohe and Kawa Streams have been diverted. Remnants of the original stone wall along the bay side exist for most of that segment, but during reconstruction, the pond wall was probably widened by in filling inside and along the original wall. A variety of materials were used from that time to repair the wall including concrete rubble, concrete blocks, and soil. The three existing gates are made of reinforced concrete with concrete sills…. One gate is about eight feet wide, the other two are six feet wide. The pond wall is up to 10 feet wide in some places and the inside of the wall appears to be lined with soil, no remnants of stone walls on the inside of the pond are obvious.
>
> At present, water flows with the tide through two of the gates, but the small gate near Kawa Stream is largely blocked by sediment and mangrove infestation and can pass only small volumes of water during very high tides… Portions of the pond are infested with mangrove which is especially thick along the Kawa Stream side and in a delta area inside the pond where the earlier Kawa Stream freshwater gate was located (Dashiel et al. 1995: excerpts from pp1-3).

The preservation plan includes a chronology of Waikalua Loko Fishpond and adjacent areas derived through historical maps and photographs, copies of which are provided in the report. The following chronology is excerpted from Dashiell et al. (1995:8-9):

> **1850** Waikalua Loko was surrounded by *loi* and probably received fresh water from *loi* runoff, *auwai,* springs, and via gates to Kaneohe and Kawa Streams. According to Alexander's (1887) map, Kawa Stream did not enter Kaneohe Bay, rather it flowed into the upland marshes and *loi* at an elevation above Waikalua Loko.

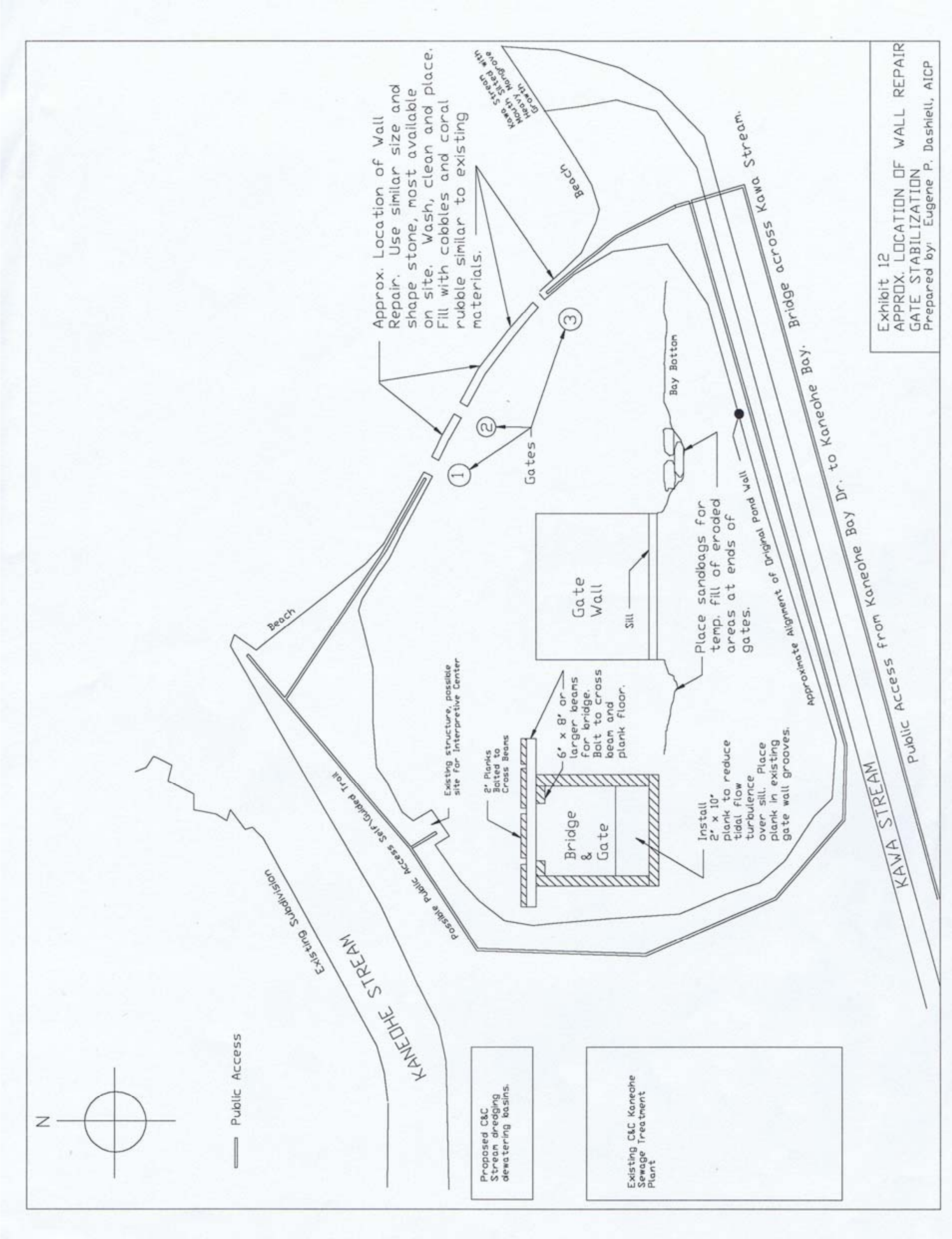

Figure 11. Plan Drawing of Waikalua Loko in 1995 Showing Wall and *Makaha* repair (Dashiell 1995:Exhibit 12)

1880 An 1887 photo (Exhibit 6) of the pond looking north shows different features than today. For example, there is a small pond for fry and this, coupled with evidence of the freshwater inflow via *auwai* and the adjacent *loi,* implies that mullet were spawned in the pond. There are trees on the pond wall.

1920 Kaneohe *ahupua'a* lands were used for taro cultivation, rice, grazing, sugar cane, and pineapple cultivation. During the late 1800's and well into the 1900's some of these land uses resulted in extensive soil erosion. A 1913 photo shows extensive *loi* adjacent to the pond (Exhibit 7). The pond may have fallen into disuse and a 1926 air photo shows the pond wall with a large break.

1930 Waikalua Loko walls are reconstructed. Three gates (those remaining today) were constructed of reinforced concrete. The wall is 9 to 12 feet wide, possibly widened during this period for access by equipment. In a photo taken in the late 1930's (frontispiece) a small structure is seen on the pond wall. Such were common near pond gates as a shelter for the gate keepers to guard the fish and to provide shade.

1940 Kaneohe Bay was dredged of more than 11 million cubic yards of coral, some used for land fill, some dumped into deep parts of the bay. This action, coupled with soil erosion in preceding years from sugar cane and pineapple cultivation permanently altered the bay's marine environment. A 1943 map appears to show inflow of Kawa stream to the pond, and a direct outlet for Kawa Stream to the bay.

1950 An air photo taken in 1949 (Exhibit 8) shows a reconstructed pond similar in form to 1926, but with a more well-defined embankment on the landward side. There appears to be a ditch or *loi* between the pond and the land… Former rice paddy or *loi* can be seen in the adjacent wetland areas… A sewage outfall was constructed into the center of the south part of Kaneohe Bay, not far from Waikalua-Loko. This added to the destruction of the bay. The remnants of the concrete pipe used for this outfall are present today along the Kawa Stream embankment.

1960 An air photo taken in 1967 (Exhibit 9) shows a channelized Kawa Stream adjacent to the pond and extending directly to Kaneohe Bay. An *auwai* or ditch adjacent to Waikalua Loko, next to the sewage treatment plant, appears to connect Kaneohe and Kawa Streams.

1970 Pond operations cease. Kawa Stream was further channelized and portions lined with concrete by the City as a flood control project to reduce flooding in the upland subdivisions. Kaneohe Stream was lined, channelized and dammed (Hoomuluhia Park project) by the City and U.S. Army Corps of Engineers (excerpted from Dashiell et al. 1995:8-9).

Following the formal acceptance of the preservation plan revision, the Waikalua Fishpond Preservation Society, a non-profit corporation (IRS 501C#3 August 1998), was formed in 1995 as a stewardship entity to care-take, stabilize, maintain, and ensure preservation of the fishpond.

The mission of the society involves three parts:

1. To preserve, stabilize, and beautify the Waikalua Loko Fishpond;
2. To educate the Windward (O`ahu) Community about ancient Hawaiian and modern Hawaiian fishpond practices: and
3. To provide an educational resource to be made available for use by educational institutions or community organizations with respect to ancient and modern Hawaiian fishpond practices.

Over the years, the society has mobilized school and community based volunteers to undertake removal of mangrove infestations within the pond, particularly along the Kawa Stream side and within a silt delta inside the ponds. Algae removal has also been carried out in the interior of the pond. The pond walls have been stabilized by using water-rounded basalt boulders and rocks, most likely displaced from the wall, collected along the shallows immediately beyond the seaside segment of the wall. Additional wall stabilization has been effected using quarried basalt boulders and rocks, as well as clay mud, and a retaining dike of stakes made from cut mangrove trunks along the inland perimeter of the pond.

The society has also produced a marine science and culture based curriculum which has been adopted by the State Department of Education. *Project Kahea Loko - A Teachers Guide to Hawaiian Fishponds*, provides educational resources for grades 4 through 12. Regular field trips by school groups have been on going for several years. There is also a well-attended community day that takes place several times each year (Waikalua Loko Preservation Society website).

RESULTS OF CURRENT ASSESSMENT

Surface assessments of the Waikalua and Aikahi terrestrial segments of the proposed Kane`ohe Kailua Force Main Number 2 corridor were conducted during the current archaeological study. Although these surface assessments discovered no new sites nor encountered any evidence of previously unrecorded or inadvertent archaeological or historic remains, they provided opportunities to examine the current conditions of the area and update any changes from available previous documentation. The proposed project boundaries on the Waikalua end incorporates a portion of one previously recorded site, Waikalua-loko Fishpond (SIHP Site 50-80-10-349). On the Aikahi end, no previously recorded sites are extant within the currently proposed project boundaries, although a number of previously recorded sites occur in adjacent areas.

Aikahi Land Segment

The current plans call for two potential options for this segment of the transmission corridor which will connect the underbay line from the H-3 Interchange to the existing Kailua Regional Wastewater Treatment Plant (see Figs. 4 & 5):

1. Option 1 – micro-tunneling from the H-3 Interchange to the KRWTP entry and open trenching within the plant boundaries, and
2. Option 2 - auger boring under the H-3 intersection and continue with open trenching to KRWTP and to the connection point within the plant.

No surface indications of any archaeologically or culturally sensitive areas were encountered during the course of surface assessment. Previous investigations in the adjacent areas to the north, discussed in a previous section of this report, have resulted largely in negative findings although six sites were reported in the area adjoining KRWTP to the north (Jackson 1993). These consisted of two surface scatters of basalt artifacts with historic material, two surficial limestone alignments, and two limestone and basalt cobble pavings. Test excavations produced negative results and interestingly no associated artifacts were found from any of the surface structural features. Some concrete and steel structures were also noted in the area. Also notable are that the soil regimes in the project corridor and in the adjoining areas are different. The parcel in which the six sites occurred occupies two soil areas, Keaau Clay to the west and Mamala Stony Silty Clay Loam to the east. The project corrider is entirely located within an area identified as Kokokahi Clay. A small area of Jaucus Sand (saline) occurs at the northeast corner of the KRWTP (see Fig. 8). Although the burials in the Mokapu Peninsula occurred in Jaucus sand JaC), the small pocket (JcC) that occurs within KRWTP is high in salinity due to the closeness of the water-table to the ground surface.

Waikalua Land Segment

The current plan calls for open trenching for the transmission line connecting the underbay line from the small spit located at the end of the artificial peninsula between Kane`ohe Stream and Waikalua-loko Fishpond to the connection within the KEPS (Fig. 12). This land segment traverses two areas of archaeological potential sensitivity; 1) portions of the northwestern side of Waikalua-loko fishpond; and 2) through the area formerly occupied by a number of Land Commission Awards (Figs. 13 and 16).

Figure 12. Aerial Image Showing Alignment of the Proposed Land Segment at Waikalua

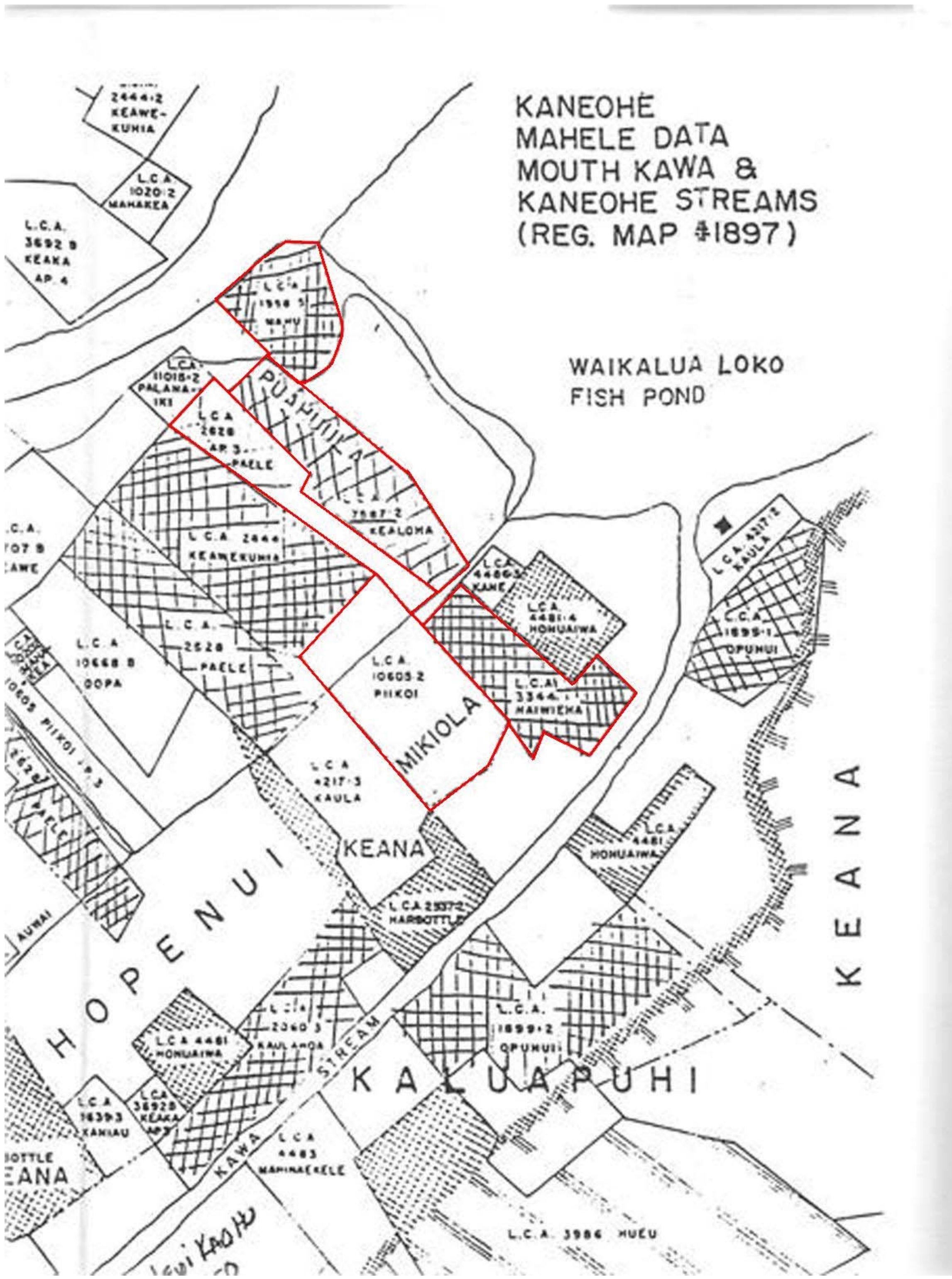

Figure 13. Portion of Redrafted Registered Map No. 1897 Showing LCA along Land Segment (Map from Cordy 1977:Fig. F-1 in Hammatt 1989:21)

Buried Fishpond Remnants

The potential of encountering buried remnants of fishpond walls from past configurations arises since the pond has undergone several modifications just within the past century. The specific details regarding prehistoric configurations are unknown and accurate definition for that period would be problematic. However, for the more recent configurations, early 20th century depictions on old topographic maps, tax maps, and aerial photographs are available (Figs. 14-16). These show certain changes, but the overall configuration appears to have been fairly stable over at least the past 80 years. Episodes of wall damage and influx of siltation from stream flow during storms is evident in the 1927 aerial in Figure 16.

In an attempt to locate possible wall remnants from past fishpond configurations, Dr. Floyd McCoy, a geologist from the Windward Community College, in coordination with archaeologist Dr. Hallett Hammatt of Cultural Surveys Hawaii, conducted 10 ground penetrating radar transects in two localities of Waikalua-loko Fishpond (Fig. 17). The imaging of the eight transects at the peninsula locality (Fig. 18) on Figures 20-22 appear to show some anomalies indicative of buried features, but whether the reflections represent old buried wall remnants are inconclusive, especially due to the extensive engineered fill forming the peninsula at this particular locality during the flood control project in the early 1970s. However, at the South Corner Locality (Fig. 19), the reflections that appear on the imaging of Transects 10 and 11 (Fig. 23) may represent the opening or *makaha* where Kawa Stream formerly entered Waikalua-loko Fishpond. The modifications in and near this locality that took place during the flood control activities consisted of stream realignment and earth moving rather than the placement of extensive engineered rock fill in contrast to the Peninsula Locality.

Buried Remains of LCA

The potential for encountering buried remnants of native *kuleana* was the second area of concern regarding the land segment at Waikalua. As shown on Figure 13, the alignment crosses five Land Commission Awards; 1958:5 to Kukeliikahaoa and Mahu, 7687:2 to Kealoha, 2628:3 to Paele, 10605:2 to Pi`ikoi, and 3344 to Naiwieha. Of these five, three are described as *lo`i* in the parcel descriptions. Based on the location and distribution of these parcels along a central `auwai, all of these were very likely agricultural lots. In 1913, the whole area inland of Waikalua-loko Fishpond is occupied by *lo`i* as shown on the photograph from that year (Fig. 24).

Systematic subsurface testing, employing backhoe trenching was undertaken by Cultural Surveys Hawaii during the course of their survey for the Proposed Bay View Golf Course Expansion

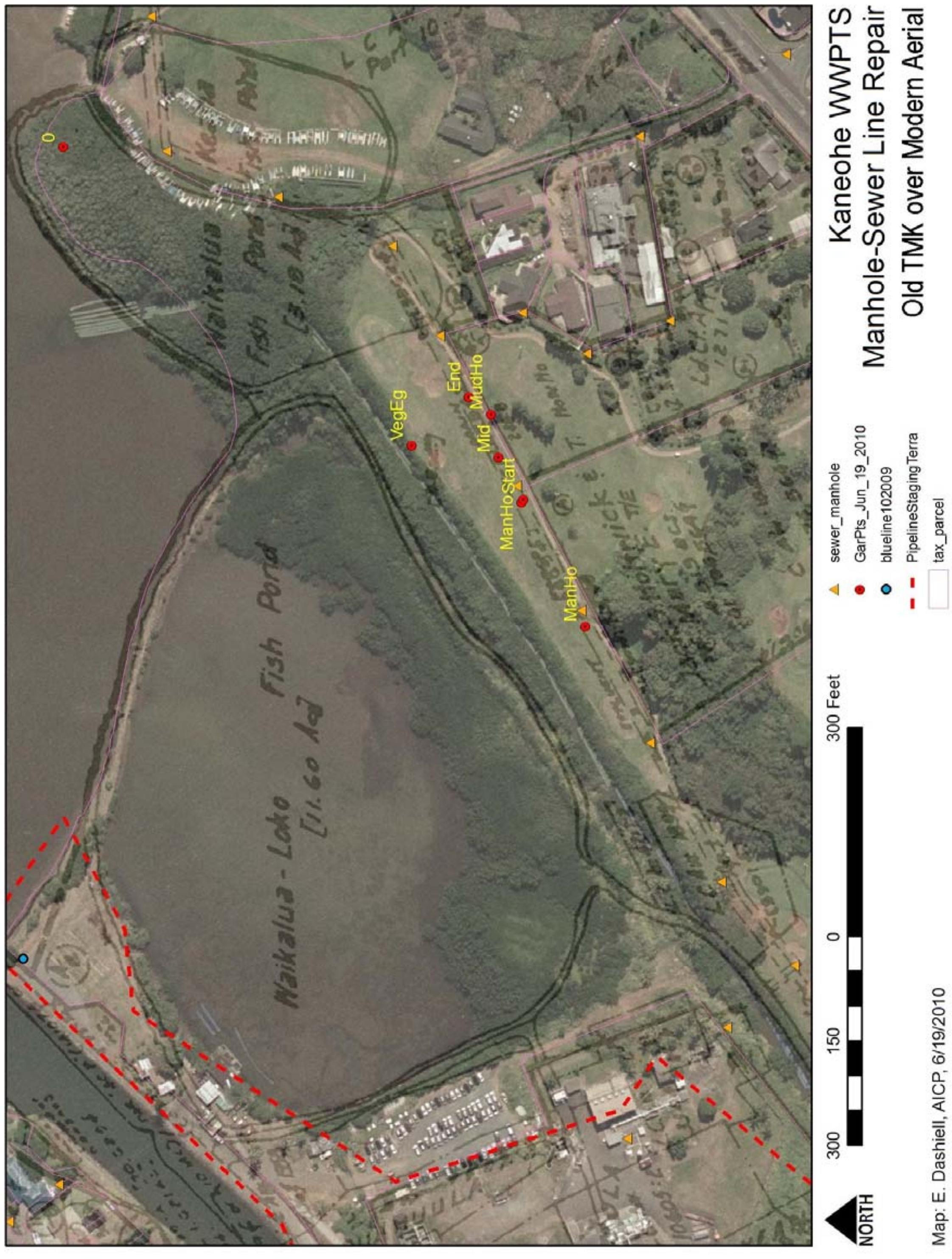

Figure 14. Old TMK (1930s) Waikalua-loko Configuration Overlaid on Modern Aerial

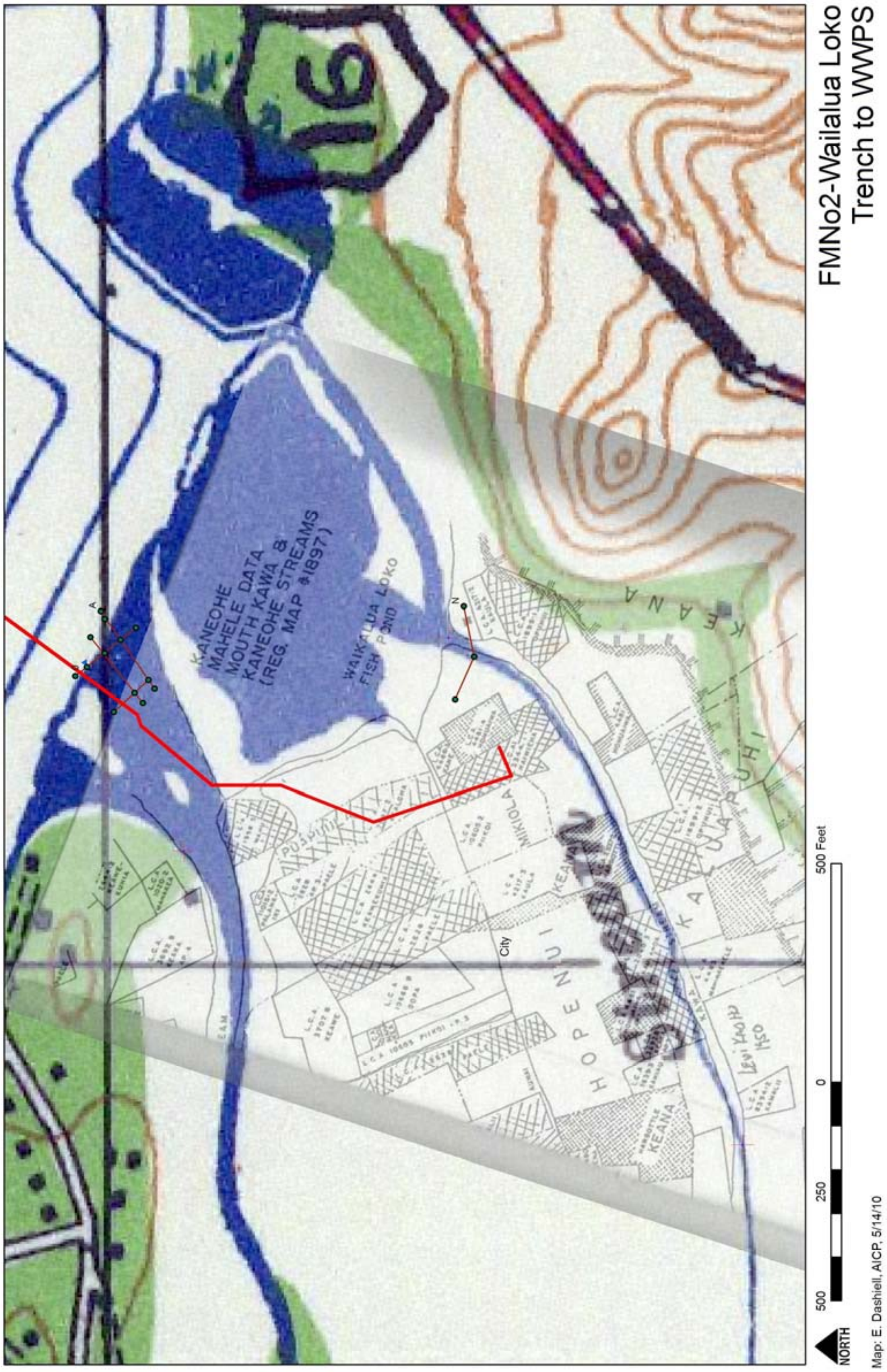

Figure 15. 1943 USGS Quadrangle Showing Different Configuration of Waikalua-loko Fishpond (Note other differences such as Kawa Stream, Kane`ohe Stream mouth, and Keana Pond)

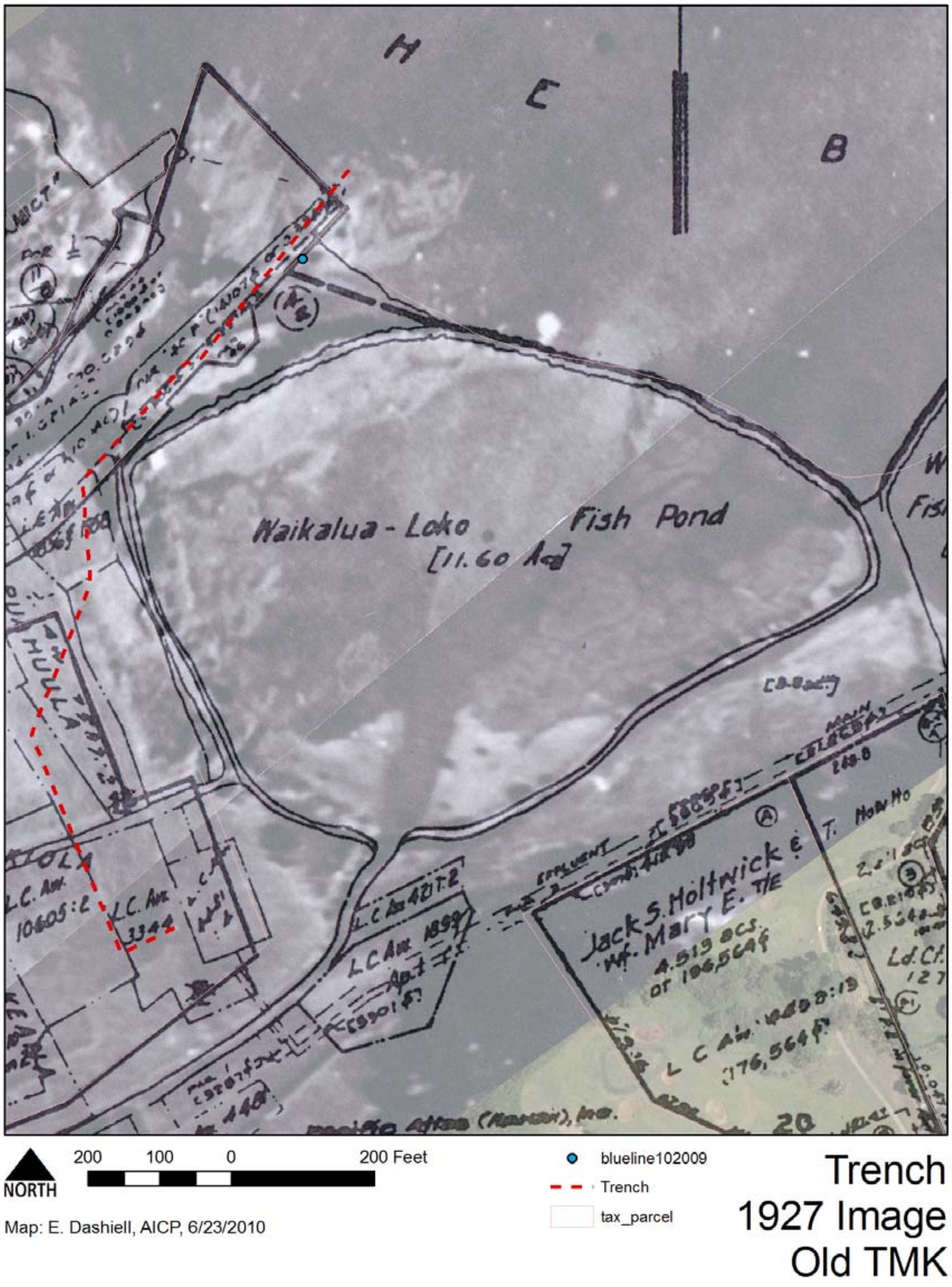

Figure 16. Old TMK (1930s) Superimposed on 1927 Aerial Image on Modern Aerial
(Note matching configuration of pond on TMK and early aerial)

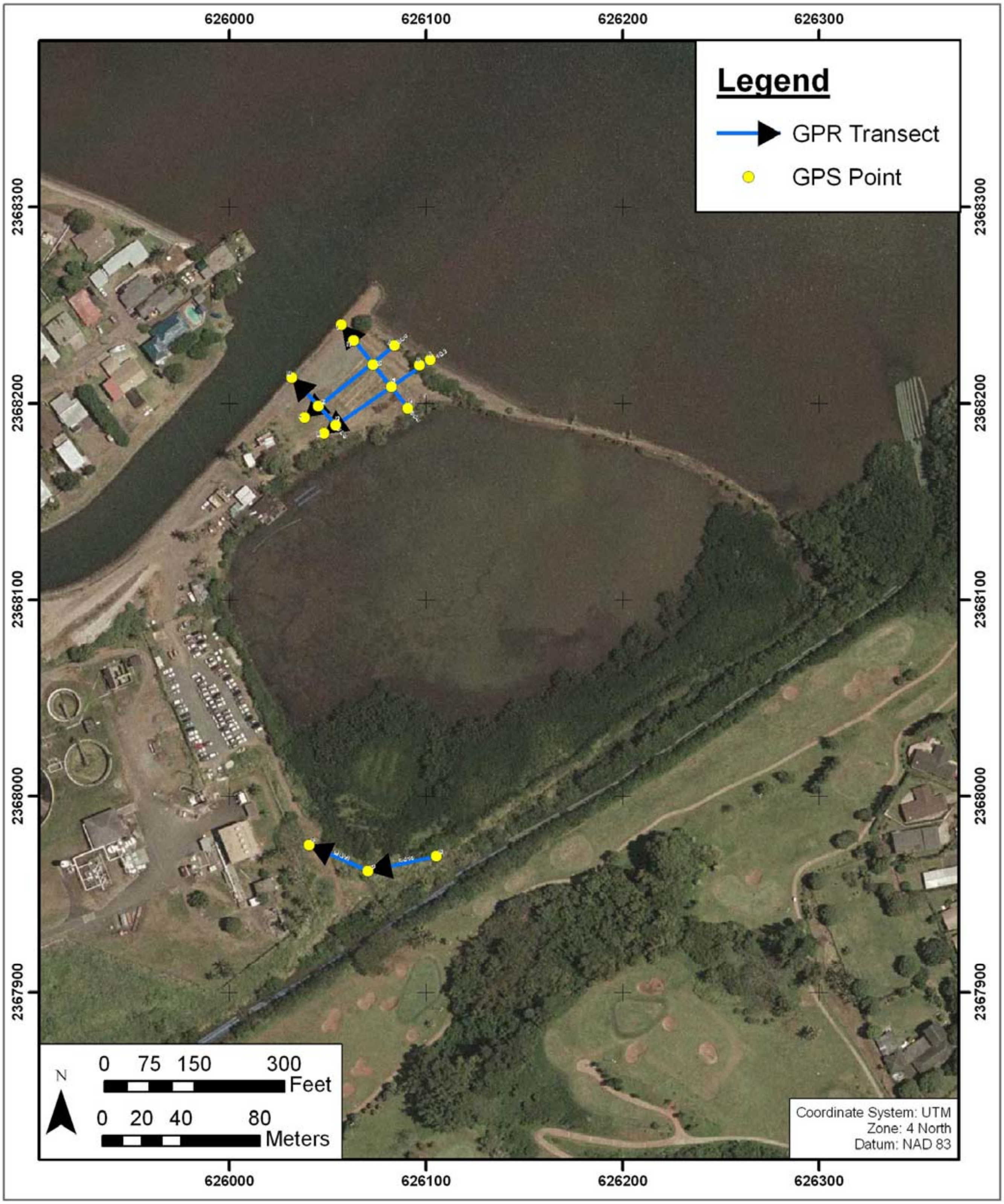

Figure 17. Aerial Showing the Two Localities where GPR Transects were Undertaken
(Courtesy of Drs. Floyd McCoy and Hallett Hammatt)

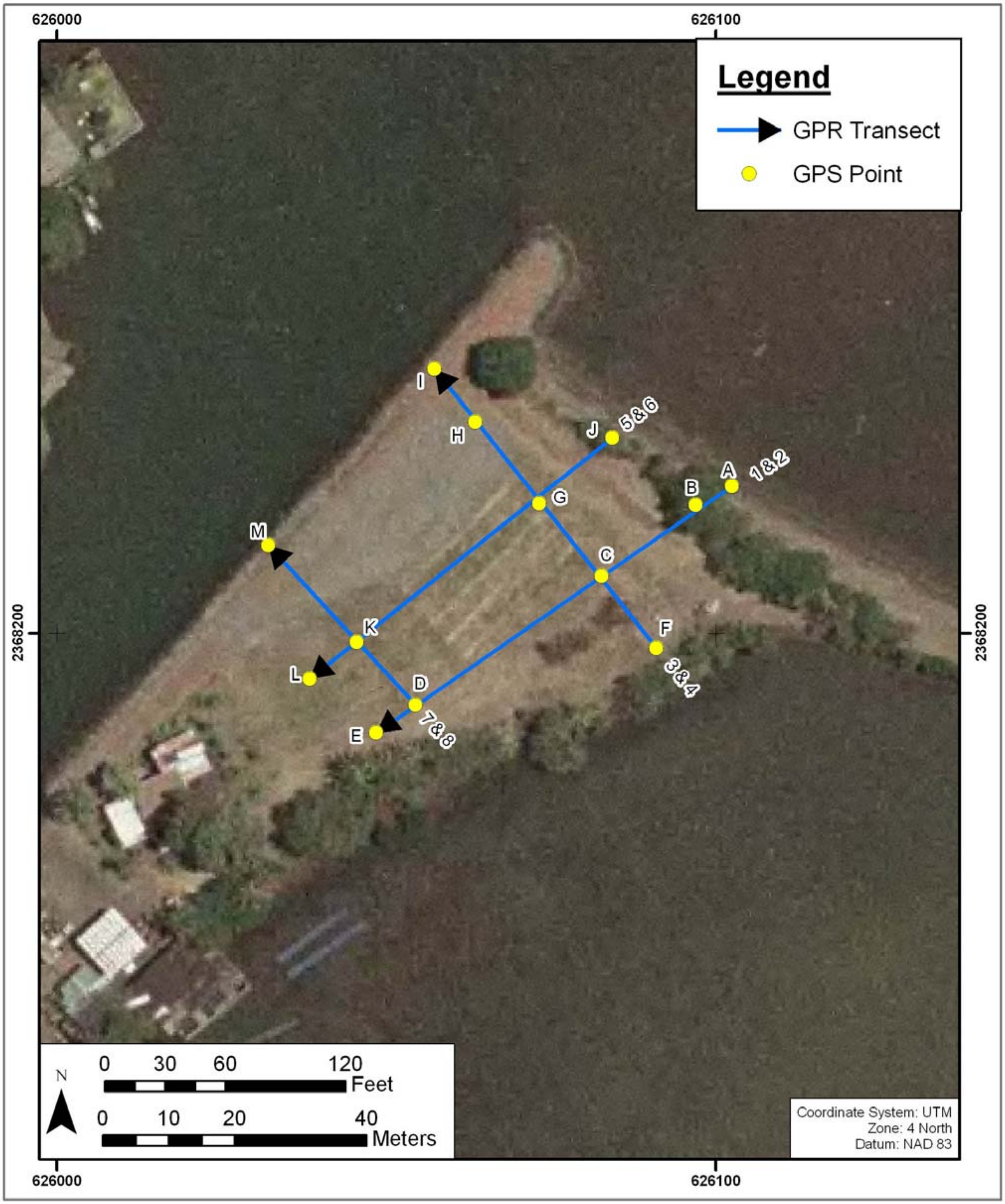

Figure 18. Detail of Peninsula Locality Transects
(Courtesy of Drs. Floyd McCoy and Hallett Hammatt)

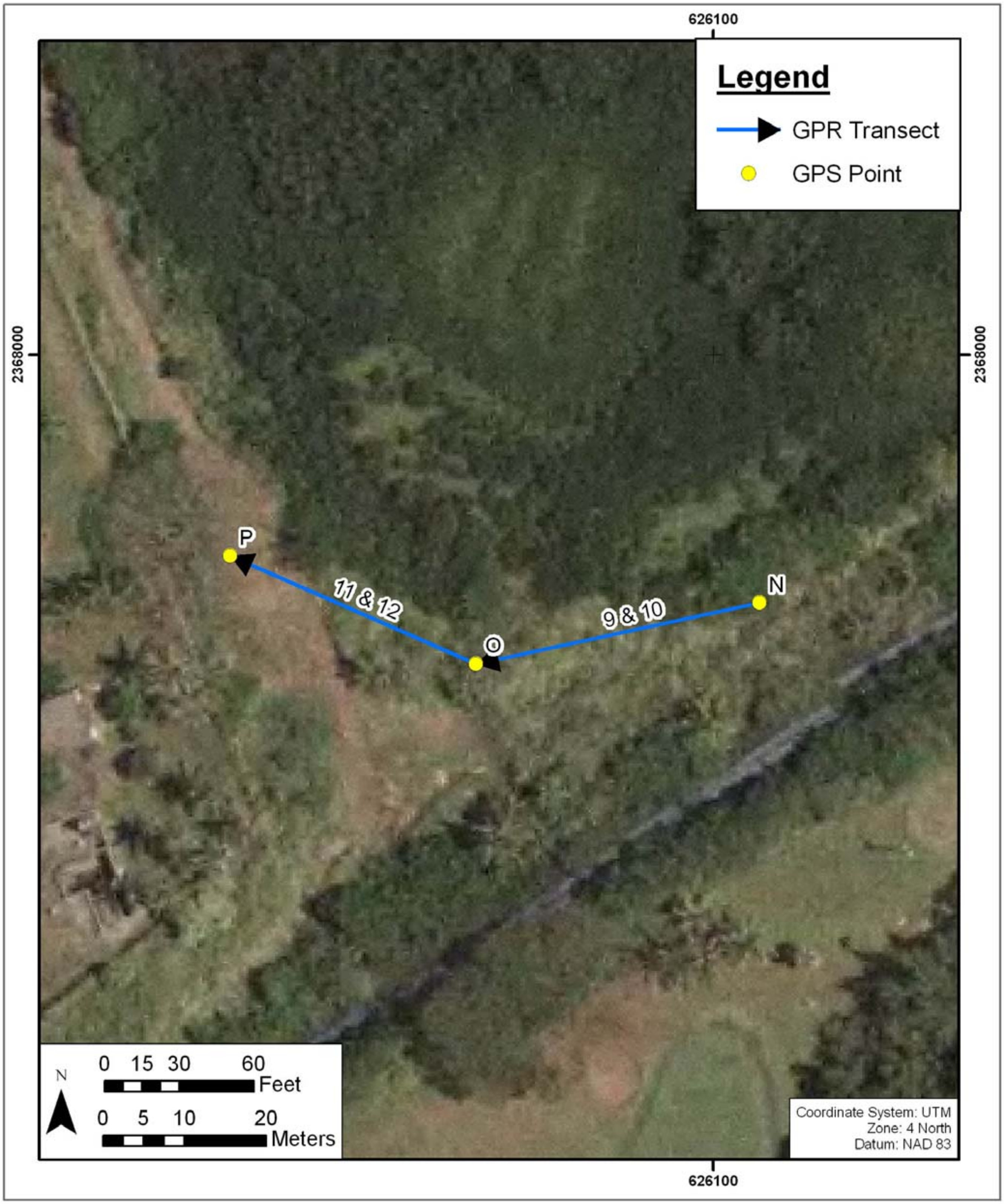

Figure 19. Detail of South Corner Locality
(Courtesy of Drs. Floyd McCoy and Hallett Hammatt)

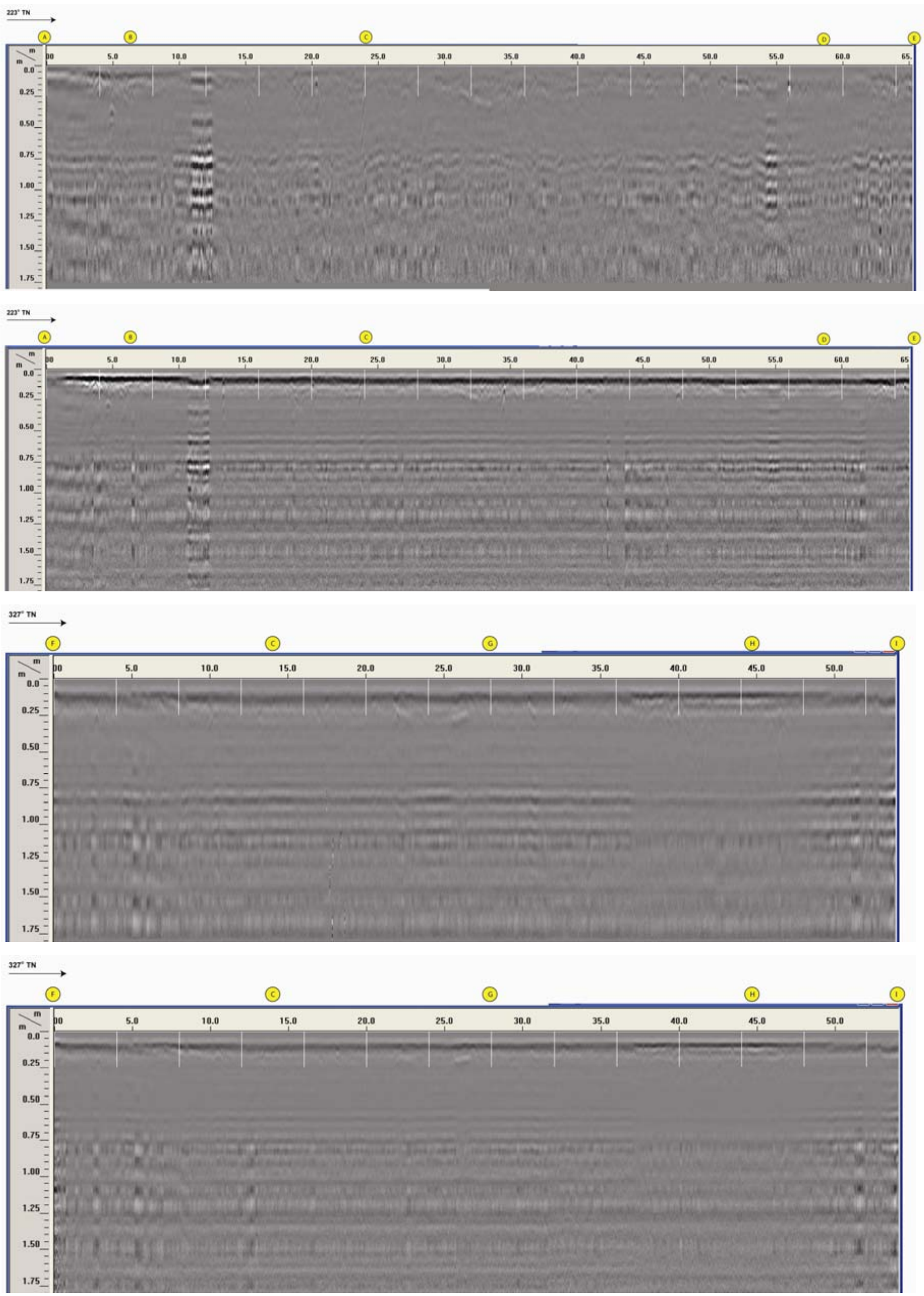

Figure 20. Imaging of Transects 1-4 at the Peninsula Locality
(Imaging Courtesy of Dr. Floyd McCoy, WCC)

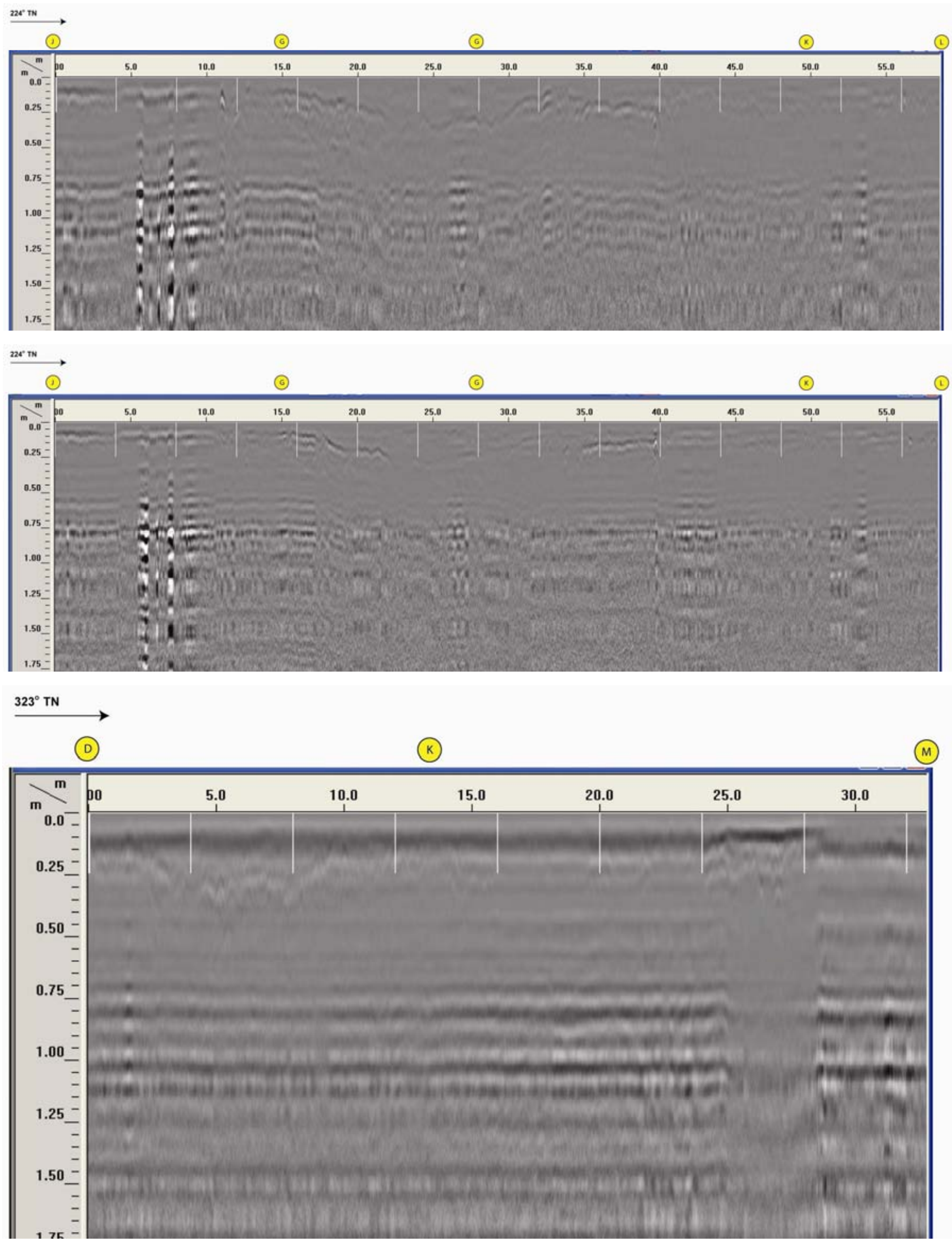

Figure 21. Imaging of Transects 5-7 at the Peninsula Locality
(Imaging Courtesy of Dr. Floyd McCoy, WCC)

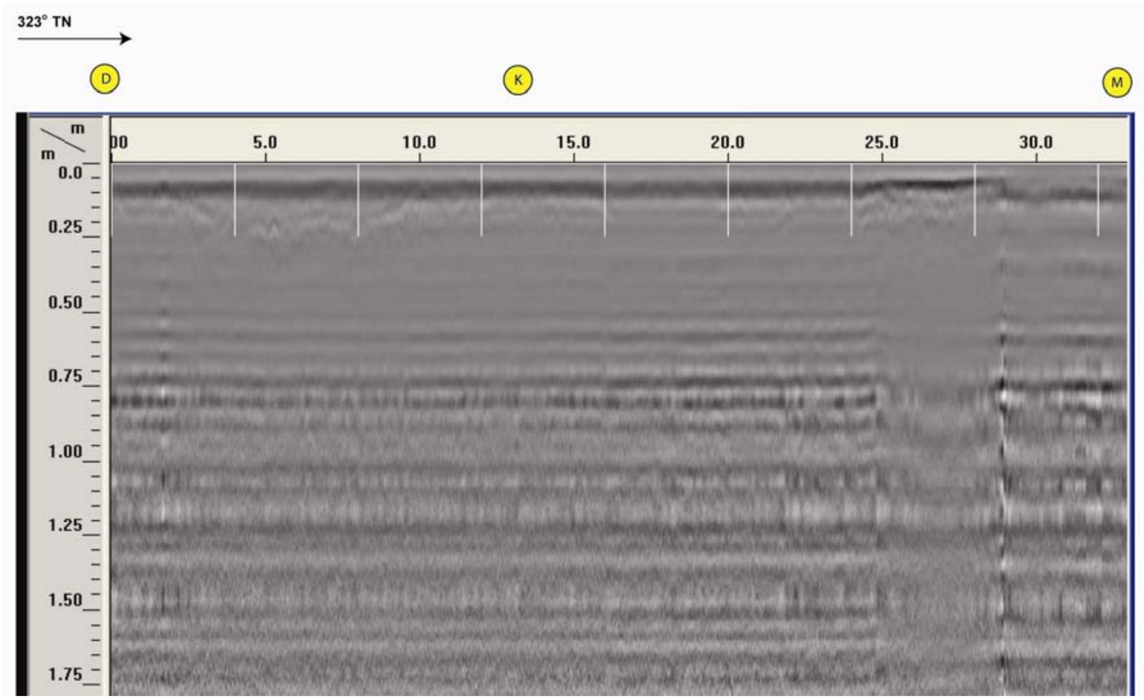

Figure 22. Imaging of Transect 8 at the Peninsula Locality
(Imaging Courtesy of Dr. Fred McCoy, WCC)

(Hammatt & Borthwick 1989). A 600-foot transect oriented north/south, located in an open pasture inland of the KEPS, and starting 200 feet north and perpendicular to Kawa Stream was tested with a series of eight backhoe trenches spaced at 50-100 foot intervals. The trenches averaged 7.5 m in length and 2.1 to 2.4 m in depth where the water-table was reached. Both trench faces were carefully examined for cultural remains, such as charcoal lenses and shell midden, as well as any remnant buried features, such as *lo`i* walls, embankments, rock alignments or cross-sections of *`auwai*. No cultural remains were encountered in any of the eight trenches. The exposed stratigraphy in all eight trenches was uniform other than slight variations in depth and thickness of each layer. Three layers were exposed. Layer I was a modern mechanically deposited fill layer of dark-grayish-brown silt loam to sandy clay, with inclusions of coral and basalt gravel with modern trash such as plastic, golf balls, and bottle glass. This fill layer was 0.60 -1.20 m in thickness. The top layer was followed by Layer IIA an A-1 Horizon 0.20 – 0.60 m in thickness. This was a reddish-brown clay loam with pronounced ferrous and clay coating in between the peds and with iron stained root casts. The upper 0.10 m typically exhibits platy structure attributable to compaction during filling. The last exposed layer which reached the

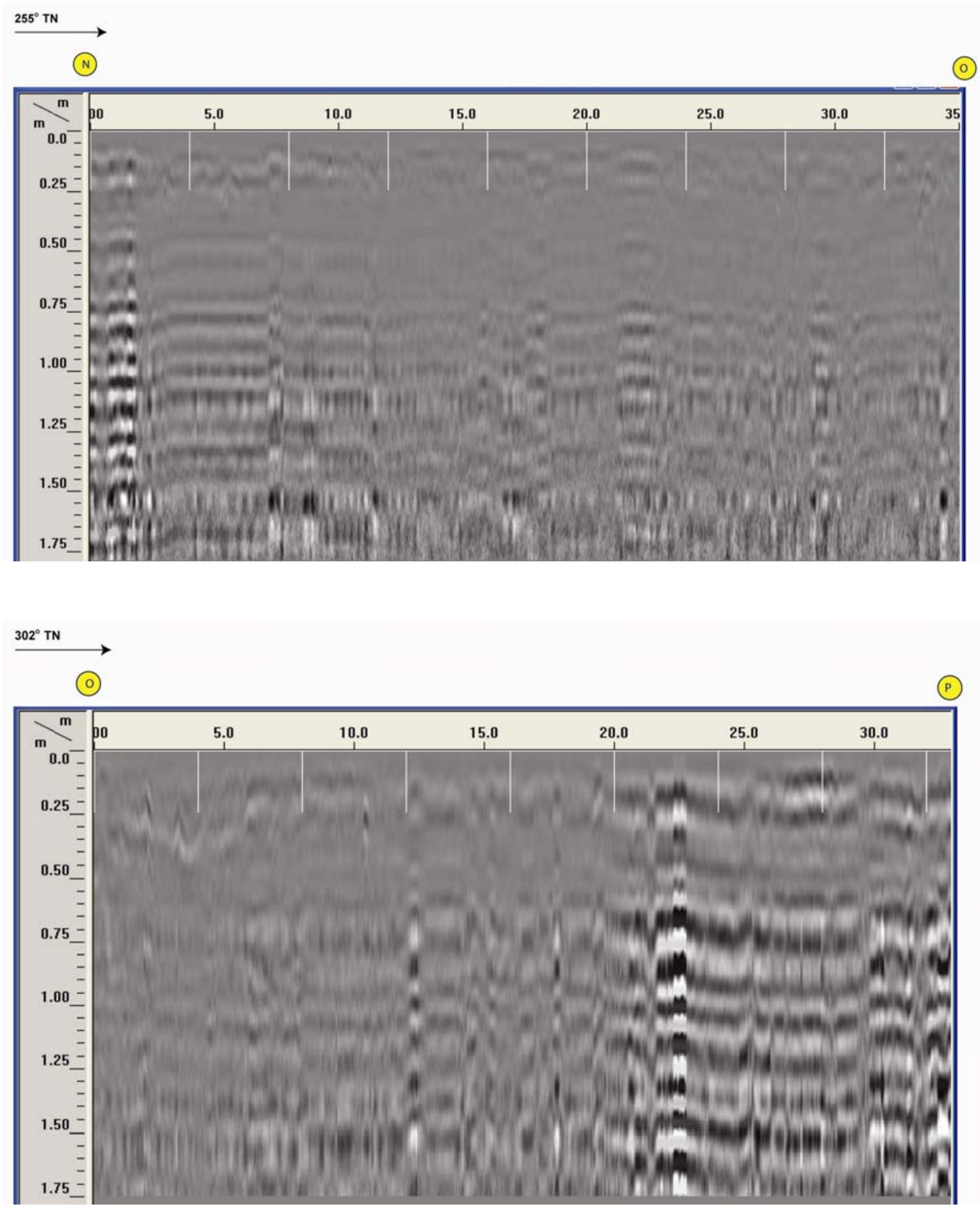

Figure 23. Imaging of Transects 10 & 11 at the South Corner Locality
(Imaging Courtesy of Dr. Floyd McCoy, WCC)

Figure 24. 1913 Photograph Showing *lo`i* Inland of Waikalua-loko Fishpond
(photograph from Dashiell et al. 1995: Exhibit 7)

water table was Layer IIB an A-3 Horizon 1.00 – 1.30+ in thickness. This layer, a gleyed clay, was a grayish blue clay with pronounced iron coating on root casts with weak organic and iron staining. The bottom portion of this layer was waterlogged. Layers IIA & B were interpreted to be the remains of a buried agricultural soil underlying and partly compacted by the mechanically deposited fill layer. The agricultural soils were considered to have derived from the same alluvial depositional origin. The distinction is due to depositional alteration, differential weathering, and variation in moisture regimes and drainage; ie, differential depositional depths. That not one of the structural features of the abundant terracing or *`auwai* were evident in the trench faces is strong evidence that the area not only underwent compaction, but the upper portions of the original ground surface was most likely also mechanically truncated and leveled prior to the deposition of fill. Thus, the current ground surface elevation is likely close to what it was when the *lo`i* complex occupied the area prior to the deposition of fill.

DISCUSSION

The proposed location of the Waikalua portal for the horizontal directionally drilled segment that will traverse beneath the bottom of Kane`ohe Bay is on the artificial peninsula which currently incorporates the northwestern wall of Waikalua-loko fishpond (see Fig.12). The former configuration of the pond during the early 1900s, as well as the prehistoric period, did not include the stream embankment structure between the pond and Kane`ohe Stream. Aerial photographs indicate that this modification initially began sometime after 1926 and possibly at the time of the recorded 1930 reconstruction and most likely renovated a few times since then to reinforce both the pond wall and to embank the Kane`ohe Stream mouth. A remnant segment of the original northwestern wall of a former, undocumented configuration of the pond may still be extant within and under the filled area. For this reason, close scrutiny of the proposed construction procedures associated with the Waikalua land segment is necessary to ensure that no component of this fishpond slated for permanent *in-situ* preservation is adversely impacted and damaged. At the same time however, the results of the analyses of aerial photographs and historic maps together with the GPR transects presented in this report confirmed that the configuration of the pond has been quite stable over the past eighty years or so. Also, with the currently proposed alignment of the land segment pipeline, no element of Waikalua-loko Fishpond as stated in the preservation mandate will be impacted.

The possibility of impacting potential buried remnants of Land Commission Award parcels traversed by the open trenching alignment which connects the underbay transmission line to the KEPS has also been relatively diminished by the previous negative results generated by the backhoe trench testing transect discussed in the previous section. The strong evidence that existing surface features of the *lo`i* complex may have been mechanically truncated prior to the deposition of fill also supports this assertion.

With two viable alternative projects still being considered by the CCH, pre-construction subsurface testing was deferred until such time as when one of the projects is selected. Coordination with the State Historic Preservation Division has been on-going.

RECOMMENDATIONS

Preconstruction subsurface testing shall be undertaken at both land segments if the underbay force main project is selected for implementation. However, the scope will vary according to the construction methodology being employed at each segment or for portions of each segment. Coordination with SHPD shall be maintained throughout the duration of archaeological procedures. All historic preservation regulations and rules shall be followed during the course of the investigation.

AIKAHI LAND SEGMENT

Two alternative schemes are currently being considered, micro-tunneling and open trenching. Should micro-tunneling be chosen, any jacking pit or other access point localities shall be tested prior to construction. If open trenching is chosen, then pre-construction spot testing shall be conducted. Open trenching will be undertaken within the KRWTP. Contingent on the results of the testing procedure, an archaeological monitoring plan shall be prepared for approval prior to commencement of any ground disturbing construction activities.

WAIKALUA LAND SEGMENT

Open trenching is slated for this alignment. For the portion (roughly the *makai* half) of the segment within the artificial peninsula and adjacent to the existing wall of Waikalua-loko Fishpond, archaeological monitoring shall be undertaken. Due to the nature and purpose of this man made embankment, the least amount of disturbance is recommended, thus monitoring during construction of the HDD portal and the open trenching in this portion of the land segment is recommended. A monitoring plan shall be prepared for review and approval by SHPD prior to commencement of any construction-related ground disturbing activities.

For the *mauka* half of the segment, preconstruction spot testing is recommended in selected locations along the footprint of the land segment corridor. Contingent on the results of the testing, the preparation of an archaeological monitoring plan may be required for review and approval by SHPD prior to commencement of any construction-related ground disturbing procedures.

Based on discussions with the SHPD Administrator, the O`ahu Island Staff Archaeologist, as well as Mr. Herb Lee of the Waikalua-loko Fishpond Preservation Society, during monitoring of the *makai* half of the land segment, should any boulders or stones suitable for use by the stewardship group in stabilizing or restoring the pond walls be encountered, these shall be recovered and stockpiled on the peninsula area beyond the construction zone.

Finally, as an interim protection measure during construction, a buffer zone of roughly 30 feet shall be established along the land-based perimeter of Waikalua-loko Fishpond to prevent inadvertent intrusions and damage to the structural components of the fishpond (Fig. 25)..

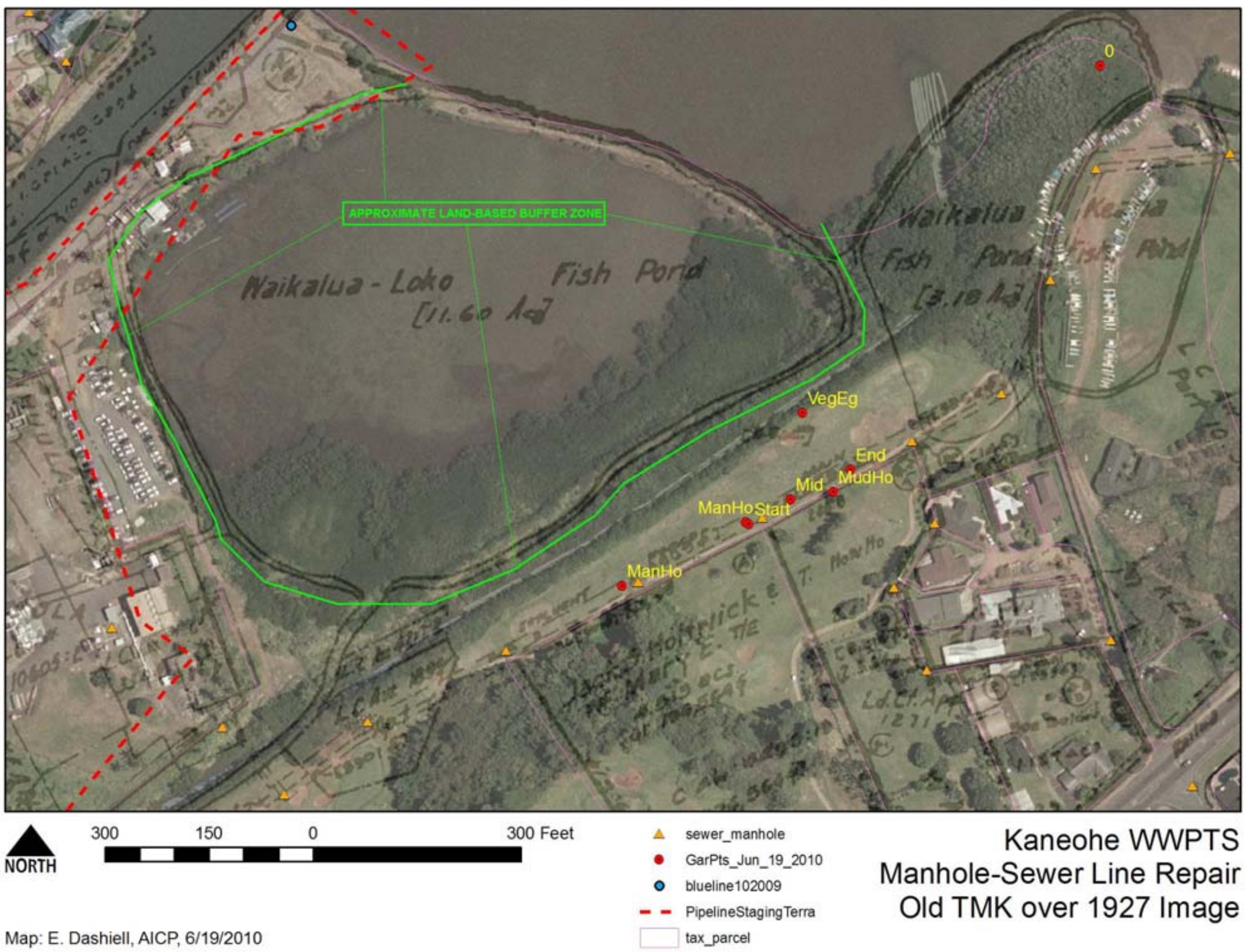

Figure 25. Showing the 30-foot Pond Perimeter Buffer Zone (in green)

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APPENDIX A

Waikalua Loko 50-80-10-349

Excerpted from:

Hawaiian Fishpond Study 1989

By:

DHM, Inc

and

Applied Research Group
Bishop Museum

Waikalua (map #56)

SITE #: State 50-80-10-349; BPBM 50-Oa-G5-11

LOCATION
AHUPUA'A/DISTRICT/ISLAND: Kane'ohe/Ko'olaupoko/O'ahu
ADDRESS: 45-231 Kulauli St.
TMK: 4-5-30:1 (portion)
USGS QUAD: Kaneohe

TYPE: I

CLASS: IIA
INTEGRITY:
WALL CONDITION*: poor to good
AMOUNT OF SILTATION*: moderate
EXTENT OF VEGETATION ENCROACHMENT: minimal
NRHP CRITERIA: A--yes; B--no; C--yes; D--yes

SIZE: 4.7 hectares (11.6 acres)

WALL: 433 m (1420 ft) long; 3.5 m *(11.5 ft) wide; 1 m* (3 ft) high.

CONSTRUCTION*: seaward facing of angular and waterworn basalt, small boulders and cobble with cobble fill.

SLUICE(S)*: 3

OWNERSHIP: Pacific Atlas (Hawaii), Inc., Ala Moana Building Suite 1212, Honolulu, Hawaii 96814

HAWAII/NATIONAL REGISTER STATUS: no/no

REFERENCES:
Apple and Kikuchi, 1975
McAllister, 1933
MINARK, 1989

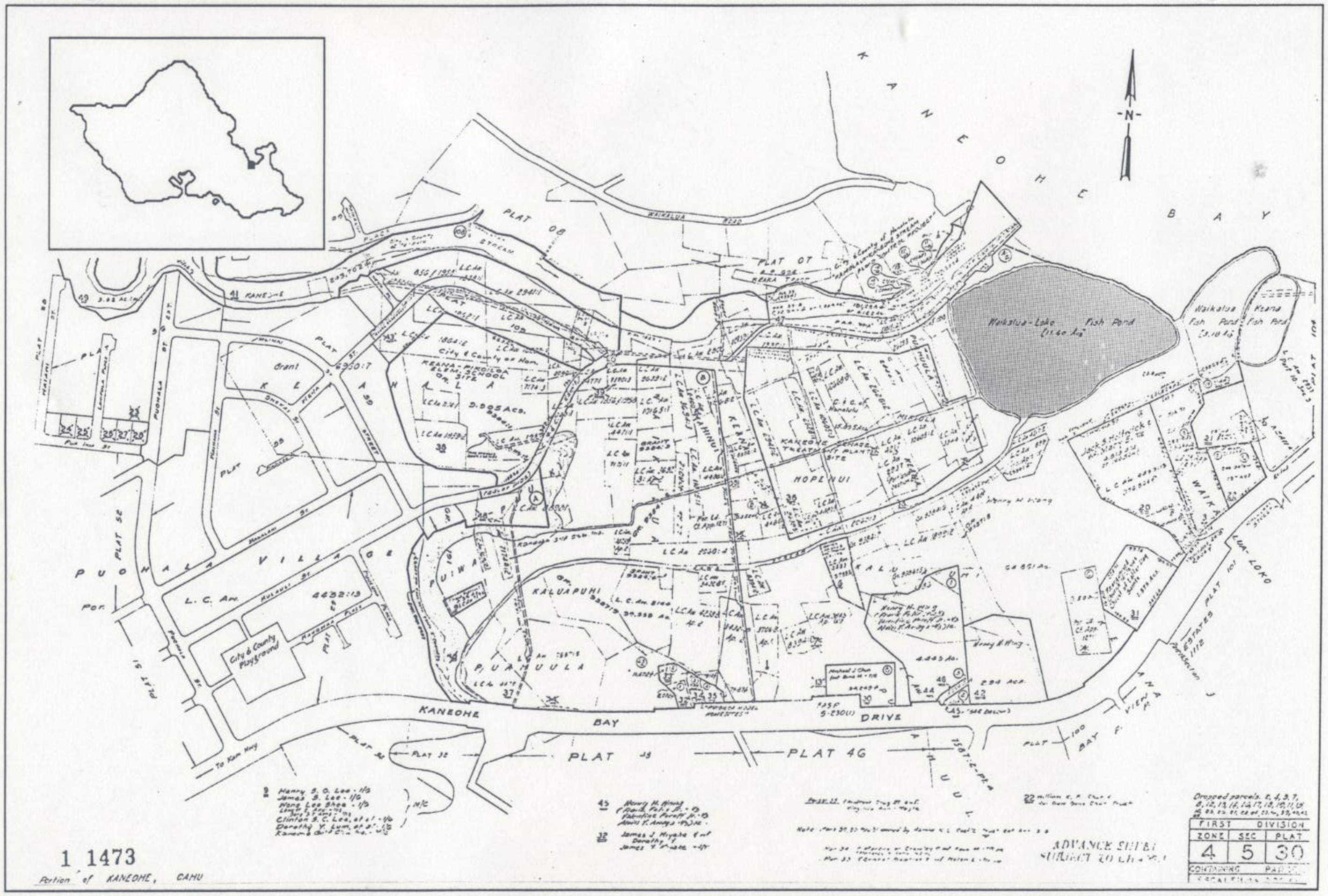
*FIELD CHECK: 28 June 1989

SURROUNDING LAND USES: P-2, P-1, R-10

SPECIAL ENVIRONMENTAL FACTORS: The Kaneohe Sewage Treatment Plant and an auto towing operation are located on the southwestern side of the fishpond.

WATER QUALITY: CLASS AA

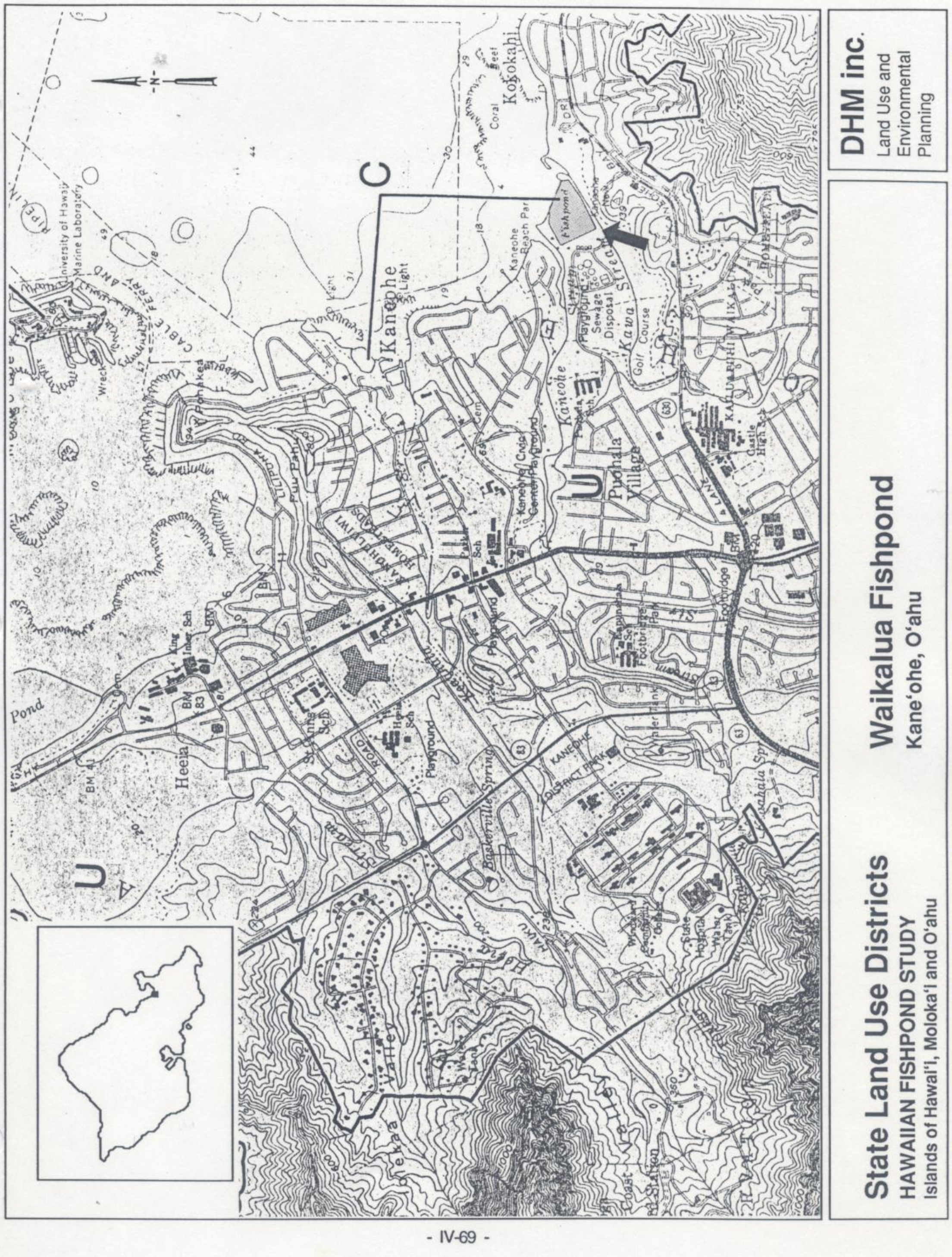
GENERAL LAND CLASS: 6 (CONSERVATION)



Tax Map
HAWAIIAN FISHPOND STUDY
Islands of Hawai'i, Moloka'i and O'ahu

Waikalua Fishpond
Kane'ohe, O'ahu (Portion of TMK: 4-5-30:1)

DHM inc.
Land Use and Environmental Planning


State Land Use Districts
HAWAIIAN FISHPOND STUDY
Islands of Hawai'i, Moloka'i and O'ahu
Waikalua Fishpond
Kane'ohe, O'ahu
DHM inc.
Land Use and Environmental Planning

- IV-69 -

State Conservation District Subzones

HAWAIIAN FISHPOND STUDY

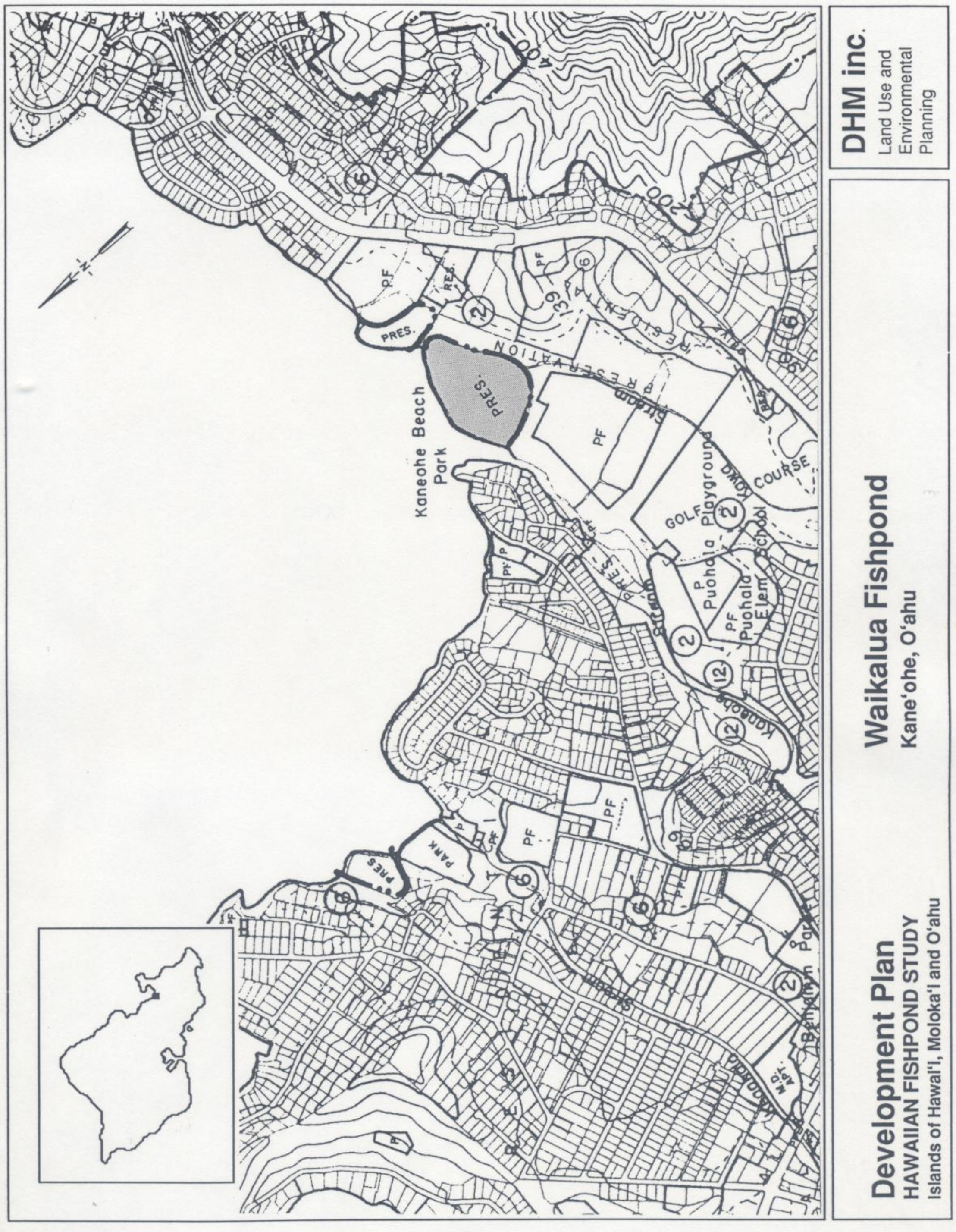
Islands of Hawai'i, Moloka'i and O'ahu

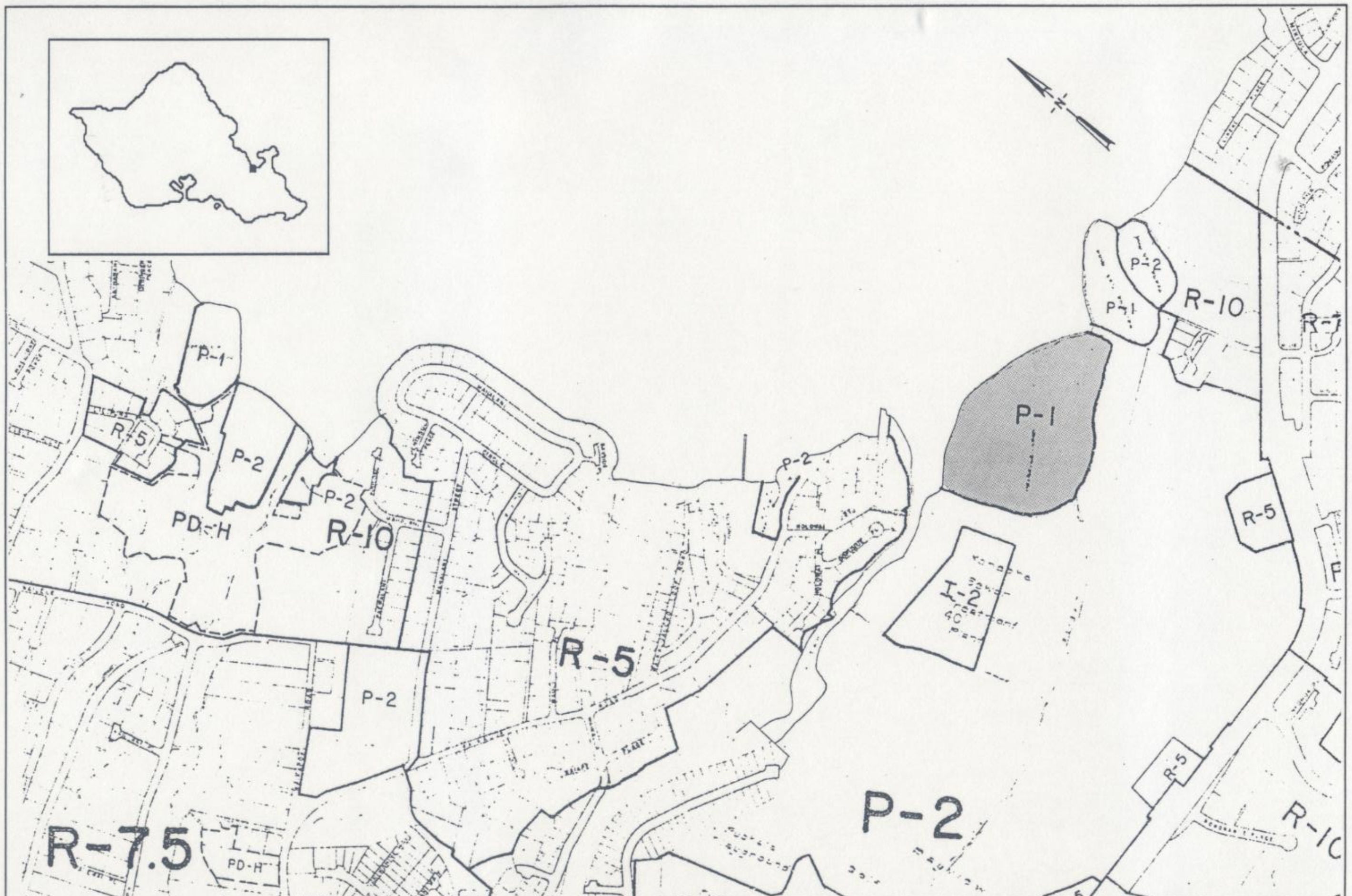
Waikalua Fishpond

Kane'ohe, O'ahu

DHM inc.

Land Use and Environmental Planning


Development Plan
HAWAIIAN FISHPOND STUDY
Islands of Hawai'i, Moloka'i and O'ahu
Waikalua Fishpond
Kane'ohe, O'ahu
DHM inc.
Land Use and
Environmental
Planning
Kaneohe Beach
Park
PRES.
PF
GOLF COURSE
Puohala Playground
Puohala Elem. School
PARK
PRESERVATION
RESIDENTIAL



Zoning Map
HAWAIIAN FISHPOND STUDY
Islands of Hawai'i, Moloka'i and O'ahu

Waikalua Fishpond
Kane'ohe, O'ahu

DHM inc.
Land Use and
Environmental
Planning

WAIKALUA FISHPOND, O'AHU. The aerial view of Waikalua Fishpond looking southwest, shows an overall view of the fishpond's relationship to the adjacent City and County of Honolulu Kane'ohe Sewage Treatment Plant and surrounding residential areas (May 25, 1989, DHM neg. no. Oa-43-24).

WAIKALUA FISHPOND, O'AHU. Aerial view to the southeast of Waikalua Fishpond with Kane'ohe stream in the foreground. (May 25, 1989, BPBM neg. no. Oa(a)-515-5).

Appendix F

Archaeological Literature Review and Field Inspection for the Proposed Kaneohe – Kailua Wastewater Conveyance and Treatment Facilities Project Alternative 2 – Tunnel Route

Kaneohe Ahupuaa, Koolaupoko District, Oahu Island

Cultural Surveys Hawaii, Inc.

November 2010

Archaeological Literature Review and Field Inspection for the Proposed Kāne‘ohe-Kailua Wastewater Conveyance and Treatment Facilities Project Alternative 2 – Tunnel Route Kāne‘ohe Ahupua‘a, Ko‘olaupoko District, O‘ahu Island

TMK: [1] 4-2-15:09; 4-2-17:01, 16, 18, 21; 4-4-11:03, 81, 82, 83; 4-4-12:01, 02, 64, 65; 4-5-30:01, 36; 4-5-31:76; 4-5-32:01; 4-5-38:01; 4-5-100:01, 02, 03, 04, 52; 4-5-101:33, 34, 35, 36, 37, 38

Prepared for

Wilson Okamoto Corporation

Prepared by

Randy Groza, M.A.,

David W. Shideler, M.A.,

and

Hallett H. Hammatt, Ph.D.

Cultural Surveys Hawai‘i, Inc.

Kailua, Hawai‘i

(Job Code: KANEOHE 14)

November 2010

O‘ahu Office
P.O. Box 1114
Kailua, Hawai‘i 96734
Ph.: (808) 262-9972
Fax: (808) 262-4950

www.culturalsurveys.com

Maui Office
1993 Main St.
Wailuku, Hawai‘i 96793
Ph: (808) 242-9882
Fax: (808) 244-1994

Management Summary

Reference	Archaeological Literature Review and Field Inspection for the Proposed Kāneʻohe-Kailua Wastewater Conveyance and Treatment Facilities Project, Alternative 2 – Tunnel Route, Kāneʻohe Ahupuaʻa, Koʻolaupoko District, Oʻahu Island (TMK: [1] TMK: [1] 4-2-15:09; 4-2-17:01, 16, 18, 21; 4-4-11:03, 81, 82, 83; 4-4-12:01, 02, 64, 65; 4-5-30:01, 36; 4-5-31:76; 4-5-32:01; 4-5-38:01; 4-5-100:01, 02, 03, 04, 52; 4-5-101:33, 34, 35, 36, 37, 38) (Groza et al. 2010)
Date	November 2010
Project Number	Cultural Surveys Hawaiʻi, Inc. (CSH) Job Code: KANEOHE 14
Investigation Permit Number	The fieldwork component of the archaeological literature review and field inspection study was carried out under CSH's annual archaeological permit # 10-10 issued by the Hawaiʻi State Historic Preservation Division/Department of Land and Natural Resources (SHPD/DLNR), per Hawaiʻi Administrative Rules (HAR) Chapter 13-282.
Project Location	The approximately 4.8 km (3 mi.) long subsurface corridor, located *mauka* (upland) of the southeastern portion of Kāneʻohe Bay, between and including the 15-acre Kāneʻohe Wastewater Pre-Treatment Facility (WWPTF) and the 25-acre Kailua Wastewater Treatment Plant (WWTP) will be aligned to traverse mostly under the Oneawa Hills range *mauka* of Kāneʻohe Bay Drive. The project area also includes a tunnel access shaft adjacent to Mōkapu Saddle Road at H-3 within an approximately 1.6-acre parcel. The project area is depicted on the U.S. Geological Survey 7.5-Minute Series Topographic Map, Kāneʻohe (1998) and Mōkapu Point (1998) quadrangles. Two alternative alignments (i.e. Alternatives 1-2) have been proposed for the project. The current study is for Alignment 2; the alternative solution involves the construction of a force main and is under preparation by another firm.
Land Jurisdiction	Surface impacts associated with the proposed project would occur at facilities owned by the City and County of Honolulu (C&C). The proposed sewer tunnel alignment would primarily run beneath the Oneawa Hills, primarily owned by Kaneohe Ranch. The proposed tunnel access shaft location is owned by the Board of Water Supply.
Agencies	State of Hawaiʻi Department of Land and Natural Resources/State Historic Preservation Division (DLNR/SHPD) City and County of Honolulu Department of Environmental Services (ENV) Honolulu Board of Water Supply

Project Description	The proposed Kāneʻohe-Kailua Wastewater Conveyance and Treatment Facilities Project involves the construction of a new conveyance system to supplement an existing force main carrying pre-treated wastewater from the Kāneʻohe Wastewater Pre-Treatment Facility (WWPTF) to the Kailua Regional Wastewater Treatment Plant (WWTP). The proposed Alternative 2–Tunnel Route involves construction of an approximately 13-foot (4 m) diameter tunnel between the two facilities. The floor of the tunnel would begin at a depth of approximately 35 feet (10.7 m) below sea level at the Kāneʻohe WWPTF. It would traverse approximately three miles, mostly beneath the Oneawa Hills range, reaching a floor depth between 75 feet and 80 feet (22.9 m to 24.4 m) below surface at the Kailua Regional WWTP, where the wastewater will be pumped to the surface for treatment by a new influent pump station (IPS); the IPS will be in the tunnel shaft. In addition to conveying wastewater by gravity flow, the tunnel would also serve a storage function when the volume of wastewater increases during periods of high rainfall. The tunnel alternative would allow the existing Kāneʻohe WWPTF and existing force main to be taken out of service. The proposed sewer tunnel would be constructed by tunnel boring machinery and could be staged from either the Kāneʻohe WWPTF or the Kailua Regional WWTP. An intermediate tunnel access shaft extending approximately 285 feet and 290 feet (86.9 m and 88.4 m) below surface would also be constructed near the midpoint of the tunnel just northwest of Mōkapu Saddle Road at its intersection with Interstate H-3. Two equalization basins will be installed, one within Kailua Regional WWTP and the other within Kāneʻohe WWPTF. Both of the equalization basins will extend 15 feet (4.6 m) below surface and will be buried 12 feet (3.7 m) below surface. Spoils comprised mostly of un-weathered basalt generated by the boring will be extracted through the completed portion of the tunnel.
Document Purpose	This archaeological literature review and field inspection study was completed for use as a planning document. The proposed project is subject to Hawaiʻi State environmental and historic preservation review legislation [Hawaiʻi Revised Statutes (HRS) Chapter 343 and HRS 6E-8/Hawaiʻi Administrative Rules (HAR) Chapter 13-275, respectively]. While this investigation does not fulfill the requirements of an archaeological inventory survey investigation (per HAR Chapter 13-276), it serves as a document to facilitate the proposed project's planning and supports historic preservation review compliance by assessing if there are any archaeological concerns within the study area and to develop data on the general nature, density and distribution of archaeological resources.

Fieldwork Effort	The fieldwork component of the archaeological literature review and field inspection study was accomplished on August 24, 2010 by CSH archaeologist Randy Groza, M.A., and cultural specialist Joe Genz, Ph.D. under the general supervision of Hallett H. Hammatt, Ph.D. (principle investigator). The fieldwork required one person-day to complete.
Results Summary	No surface historic properties were identified within the Kāneʻohe Wastewater Pre-Treatment Facility (WWPTF), Kailua Wastewater Treatment Plant (WWTP), and a proposed tunnel access shaft location within BWS lands northwest of Mōkapu Saddle Road at its intersection with Interstate H-3. Kāneʻohe WWPTF and Kailua WWTP were both observed to have undergone extensive land modification associated with sewer and water treatment and their related facilities. BWS lands in the vicinity of the proposed tunnel access shaft contain a large water tank, construction debris, piping, and soils for / from BWS projects. Geotechnical testing results (see Appendix A) show that basalt extends from 61 cm below surface (2 feet) to the bottom of the excavation, 98 m below surface (320.5 feet). Despite the lack of surface findings, the historic record clearly indicates that Kāneʻohe Wastewater Pre-Treatment Facility lands were something of a quilt of traditional Hawaiian habitations and taro patches as documented in the nineteen circa-1848 Land Commission Awards. This pattern of intensive habitation and intensive traditional Hawaiian agriculture may have existed for centuries prior to Western contact in this area of unique natural abundance bordered by perennial Kawa Stream to the south and the rich margins of Kāneʻohe Bay to the east. Perennial Kāneʻohe Stream was approximately 60 m to the north. A small area in the northeastern portion of Kailua WWTP contains Jaucus sand (see Figure 7). Human burials have been found throughout the Hawaiian Islands within Jaucas sand deposits. No previous archaeological studies have found historic properties and human burial remains within close proximity to the proposed project areas.
Recommendations **continued on page iv**	After the City and County of Honolulu and the EPA determine the most appropriate alternative plan for this project, CSH recommends the following if Alternative 2, the gravity tunnel, is chosen. These recommendations are based on the results of the literature review and field inspection. **Kāneʻohe WWPTF** A program of archaeological inventory survey subsurface testing is recommended in consultation with SHPD that is based on project plans and scaled to address the specific locations of planned excavations.

Recommendations continued from page iii	**Kāneʻohe WWPTF continued** Based on the findings of the archaeological inventory survey and in consultation with SHPD, monitoring is likely to be appropriate during initial subsurface excavations within Kāneʻohe WWPTF. **Waikalua Loko Fishpond** Project activities related to the proposed Kāneʻohe WWPTF upgrades should avoid direct or indirect adverse impacts to Waikalua Loko Fishpond (SIHP # 50-80-10-349) and its vicinity (TMK: [1] 4-5-030:001, por.). Consultation with SHPD and the Waikalua Loko Fishpond Preservation Society and consideration of the Waikalua Loko Fishpond Preservation Plan (Dasheill 1995) is recommended if construction staging or other activities are planned within the fishpond's vicinity. **Kailua WWTP** Jaucus sand (see Figure 7) is present within a very small area in the vicinity of the Kailua WWTP administration building in the northeastern portion of Kailua WWTP. Human burials have been found throughout the Hawaiian Islands within Jaucas sand deposits. Currently, no new facilities are planned in this area. If any subsurface disturbance is planned for this area, a program of archaeological inventory survey subsurface testing is recommended in consultation with SHPD. Based on the findings of the archaeological inventory survey and in consultation with SHPD, monitoring is likely to be appropriate during subsurface excavations within the northeast portion of Kailua WWTP. Otherwise, no further work is recommended for Kailua WWTP based on historic research, extensive development within the project area, and the lack of previous findings within the facility. **Nuʻupia Fishpond** Nuʻupia Fishpond (SIHP # 50-80-11-1002) is within Marine Corps Base Hawaii, and no adverse affects to the fishpond are anticipated as a result of the proposed project. **Proposed Tunnel Access Shaft Location** No further work is recommended for the proposed tunnel access shaft location within BWS lands northwest of Mōkapu Saddle Road at its intersection with Interstate H-3 based on geotechnical testing results showing basalt extending from 61 cm below surface (2 feet) to 98 m below surface (320.5 feet; see Appendix A). If, however, a new location for the proposed tunnel access shaft is identified, additional literature review and field inspection is recommended.

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Section 1 Introduction

1.1 Project Background

At the request of Wilson Okamoto Corporation, Cultural Surveys Hawai‘i, Inc. (CSH) prepared this archaeological literature review and field inspection study for the proposed Kāne‘ohe-Kailua Wastewater Conveyance and Treatment Facilities Project, Alternative 2 – Tunnel Route, Kāne‘ohe Ahupua‘a, Ko‘olaupoko District, O‘ahu Island (TMK: [1] 4-4-003:015; 4-4-006:016; 4-4-007:025; 4-4-011:081; 4-4-012:067 4-4-014:049; 4-4-037:014; 4-5-030:036). The approximately 4.8 km (3 mi.) long subsurface corridor, located *mauka* (upland) of the southeastern portion of Kāne‘ohe Bay, between and including the 15-acre Kāne‘ohe Wastewater Pre-Treatment Facility (WWPTF) and the 25-acre Kailua Regional Wastewater Treatment Plant (WWTP) will be aligned to traverse mostly under the Oneawa Hills range *mauka* of Kāne‘ohe Bay Drive. The project area also includes a tunnel access shaft just northwest of Mōkapu Saddle Road at H-3 within an approximately 1.6-acre parcel. The project area is depicted on the U.S. Geological Survey 7.5-Minute Series Topographic Map, Kāne‘ohe (1998) and Mōkapu Point (1998) quadrangles (Figure 1), an aerial photograph (Figure 2), and on three TMK maps (Figure 3 to Figure 5).

Two alternative alignments (i.e. Alternatives 1-2) have been proposed for the project (Figure 6). The current study is for Alignment 2; the alternative solution involves the construction of a force main and is under preparation by another firm.

The City and County of Honolulu Department of Environmental Services proposes to undertake improvements to the wastewater collection and treatment system in the Kāne‘ohe-Kailua wastewater service area. The proposed conveyance system to supplement an existing force main carrying pre-treated wastewater from the Kāne‘ohe WWPTF to the Kailua Regional WWTP involves construction of an approximately 13-foot (4 m [meter]) diameter tunnel between the two facilities. The floor of the tunnel would begin at a depth of approximately 35 feet (10.7 m) below sea level at the Kāne‘ohe WWPTF. It would traverse approximately three miles (4.8 km), mostly beneath the Oneawa Hills range, reaching a floor depth of between 75 feet and 80 feet (22.9 m to 24.4 m) below surface at the Kailua Regional WWTP, where the wastewater will be pumped to the surface for treatment by a new influent pump station (IPS); the IPS will be in the tunnel shaft. In addition to conveying wastewater by gravity flow, the tunnel would also serve a storage function when the volume of wastewater increases during periods of high rainfall. The tunnel alternative would allow the existing Kāne‘ohe WWPTF and existing force main to be taken out of service.

The proposed sewer tunnel would be constructed by tunnel-boring machinery and could be staged from either the Kāne‘ohe WWPTF or the Kailua Regional WWTP. An intermediate tunnel access shaft extending approximately 285 feet and 290 feet (86.9 m and 88.4 m) below surface would also be constructed near the midpoint of the tunnel just northwest of Mōkapu Saddle Road at its intersection with Interstate H-3. Two equalization basins will be installed, one within Kailua Regional WWTP and the other within Kāne‘ohe WWPTF. Both of the equalization basins will extend 15 feet (4.6 m) below surface and will be buried 12 feet (3.7 m) below surface.

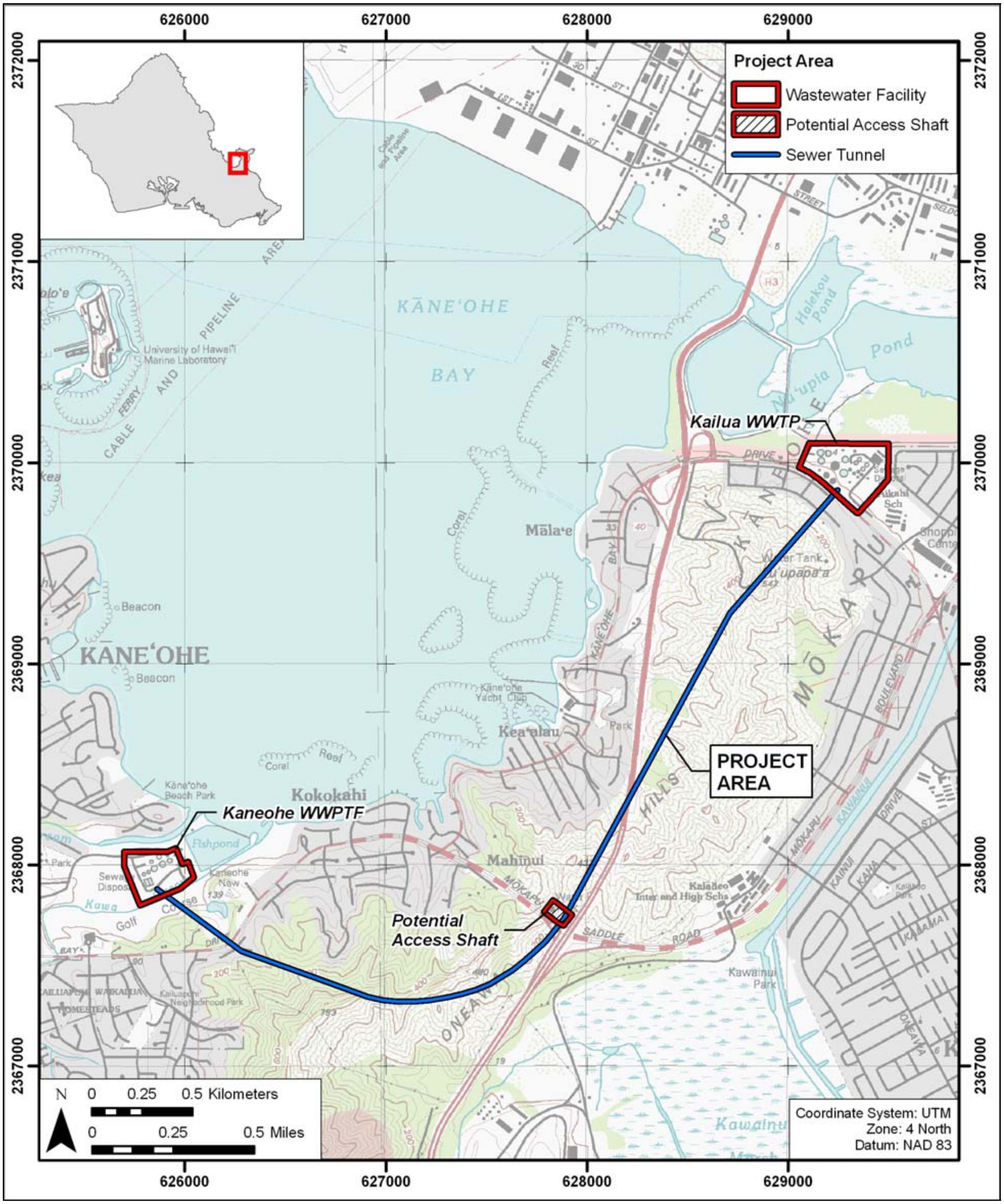

Figure 1. Portion of U.S. Geological Survey 7.5-Minute Series Topographic Map, Kāne‘ohe (1998) and Mōkapu Point (1998) quadrangles, showing the location of the project area

Figure 2. Aerial photograph (source: U.S. Geological Survey Orthoimagery 2005), showing the location of the project area

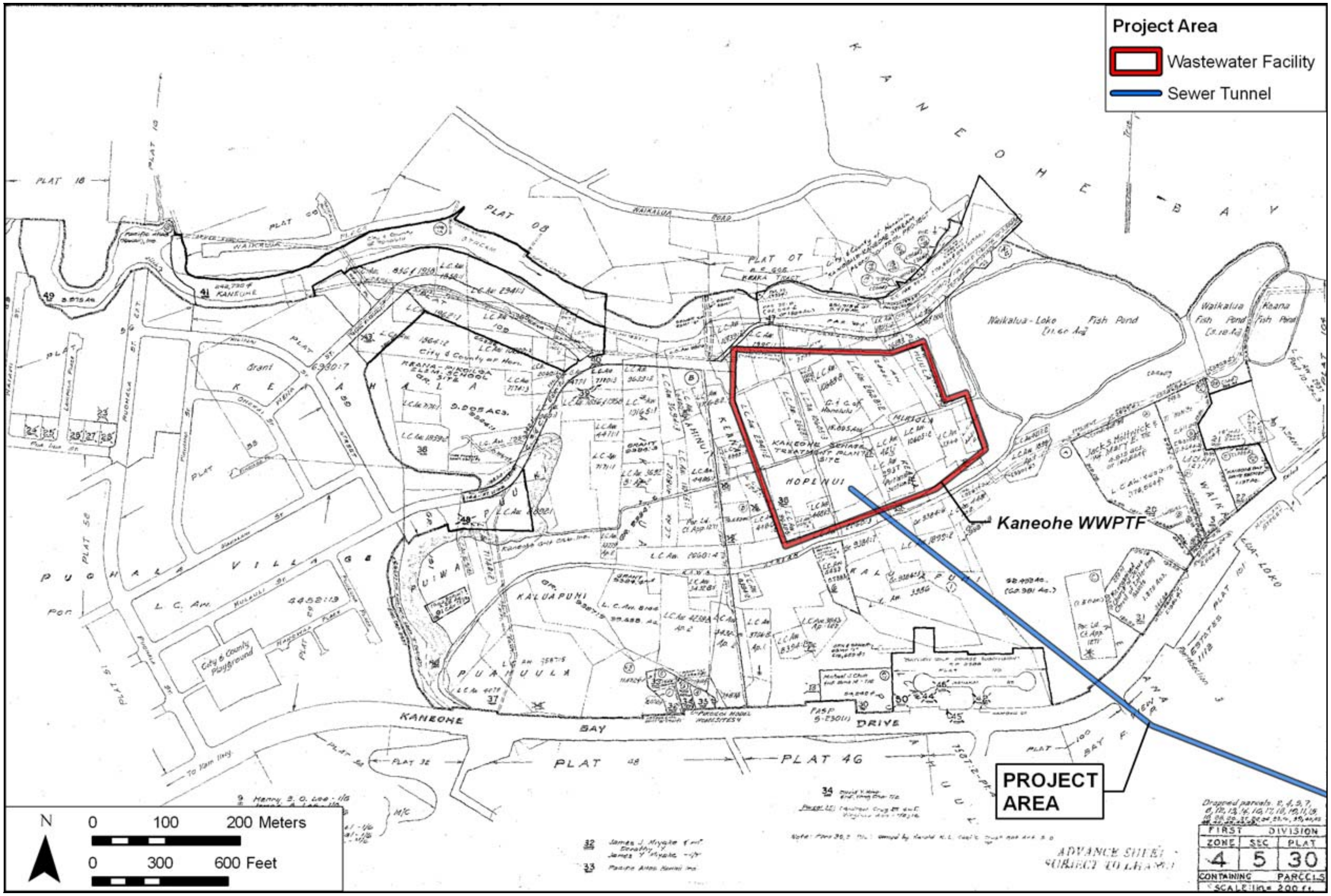

Figure 3. Tax Map Key 4-5-30, showing the Kāne‘ohe Wastewater Pre-Treatment Facility (WWPTF) portion of the project area

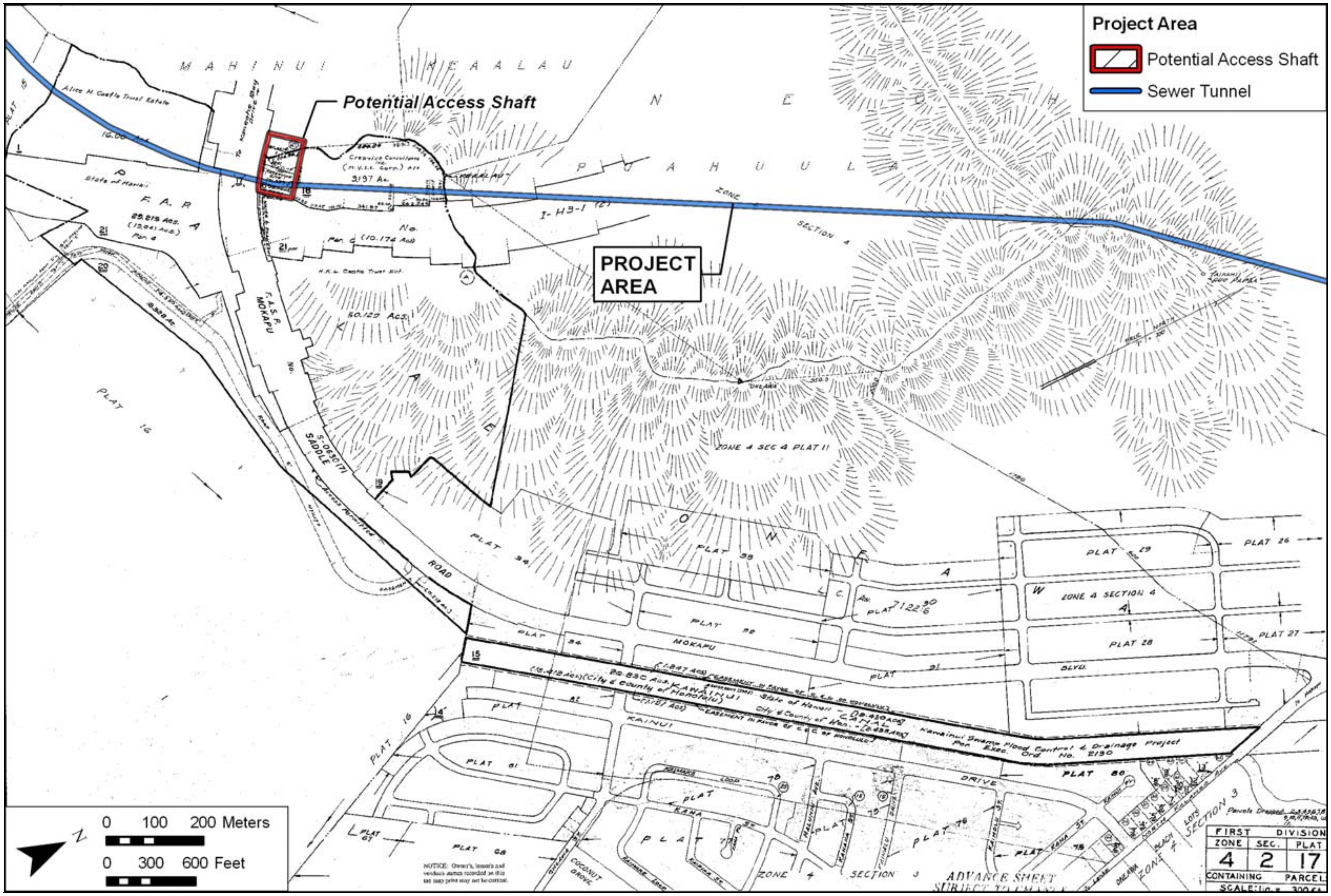

Figure 4. Tax Map Key 4-2-17, showing the Potential Access Shaft portion of the project area

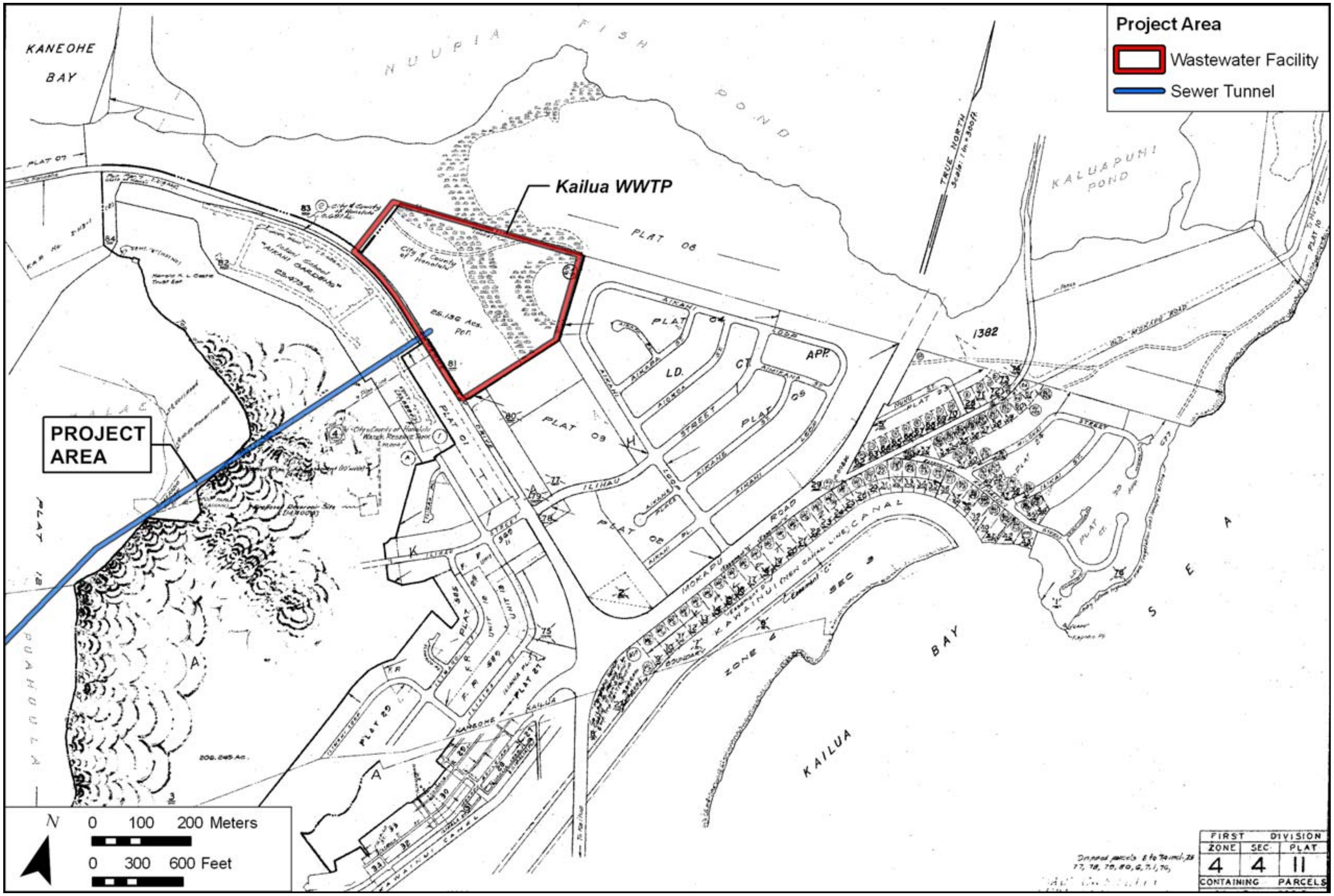

Figure 5. Tax Map Key 4-4-11, showing the Kailua Regional Wastewater Treatment Plant (WWTP) portion of the project area

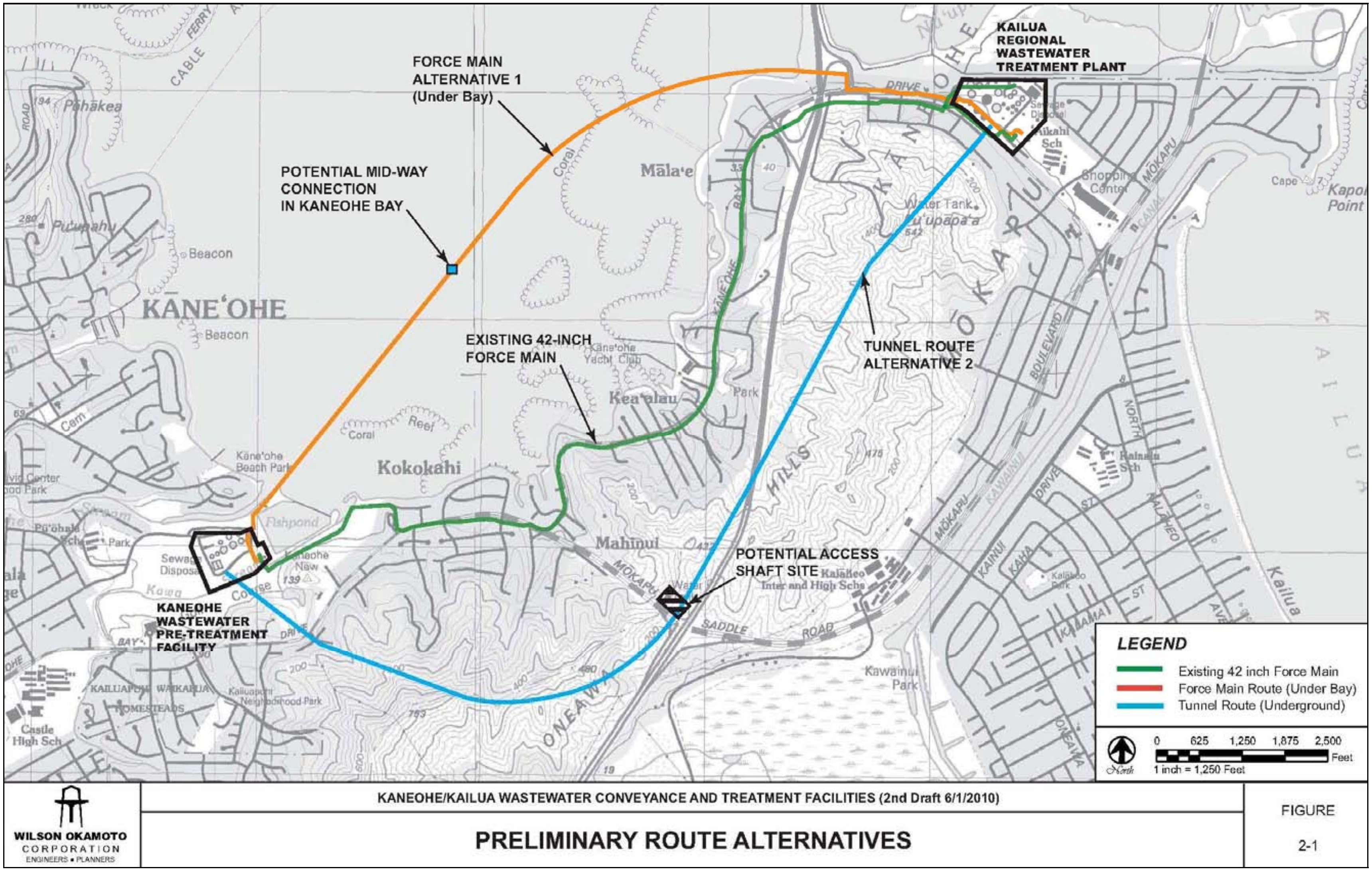

Figure 6. Project plans showing Alternative 1 and 2 (provided by Wilson Okamoto)

Near-surface land disturbance associated with the proposed project would occur in the vicinity of the Kāne'ohe WWPTF, the intermediate access shaft, and the Kailua Regional WWTP. Horizontal boring associated with the construction of the sewer tunnel would occur at depths greater than 45 feet (13.7 m) and would likely have no effect on the near-surface sediments above. Spoils comprised mostly of un-weathered basalt generated by the boring will be extracted through the completed portion of the tunnel. The basalt will be removed as crushed rock, which can be readily processed for use as construction material.

1.2 Scope of Work

The scope of work for this archaeological literature review and field inspection study was as follows:

1. Historical research including study of archival sources, historic maps, Land Commission Awards and previous archaeological reports to construct a history of land use and to determine if historic properties have been recorded in or near the project area.
2. Limited field inspection of the project area to identify any surface archaeological features and to investigate and assess the potential for impact to such sites. This assessment will identify sensitive areas that may require further investigation or mitigation before the project proceeds.
3. Preparation of a report to include the results of the historical research and the limited fieldwork with an assessment of archaeological potential based on that research with recommendations for further archaeological work. The report also provides mitigation recommendations if there are archaeologically sensitive areas that need to be taken into consideration.

1.3 Environmental Setting

1.3.1 Natural Environment

The project area is located in coastal Kāneohe, situated along the southeastern edge of Kāne'ohe Bay. The western portion of the project area begins on the coastal plain immediately inland of the Waikalua Loko Fishpond. The sewer tunnel alignment progresses southeast to the Oneawa Hills and then extends east to the proposed location of the access shaft, just *makai* (towards the ocean) of Mōkapu Saddle Road at its intersection with Interstate H-3. The sewer tunnel alignment then continues inland, primarily running beneath the Oneawa Hills. The eastern portion of the project area is on the low-lying lands of the Mōkapu Peninsula, situated between Kāne'ohe and Kailua Bays. The lands within the project area treatment areas are generally level with elevations ranging from 0 to 12 m (0 to 40 ft.) above mean sea level. Rainfall in this portion of Kāne'ohe averages 1,000 mm (40 inches) per year (Giambelluca et al. 1986).

Much of the proposed project-related excavations would occur at depths greater than 35 feet (10.7 m), which would presumably be within limestone or basalt bedrock. Soils in the portions of the project area where near-surface excavations would occur are listed from west to east as: Hanalei Silty Clay (HnA) within the vicinity of Kāne'ohe WWPT; and Alaeloa Silty Clay (ALF) within the vicinity of the intermediate tunnel shaft. Soils within the Kailua WWTP portion of the project area consist of Kokokahi Clay (KtC); Keaau Clay (KmbA); Mamala Stony Silty Clay Loam (MnC) with a very small area of Jaucus Sand (JcC) within the northeastern portion of Kailua WWTP (Figure 7).

Soils of the Hanalei Series are described as

> somewhat poorly drained to poorly drained soils on bottom lands…developed in alluvium derived from basic igneous rock….used for taro, pasture and vegetables. Vegetation on noncultivated areas is californiagrass, sensitive plant,honohono, and Java plum. (Foote et al. 1972:38-39)

Soils of the Alaeloa Series are described as

> …deep and very deep, well drained soils that formed in material weathered from basic igneous rock…..used mainly for pasture….Vegetation is guava (*Psidium guajava*), Java plum (*Eugenia cumini*), christmasberry (*Schinus terebinthifolius*), Japanese tea (*Cassia leschenaultiana*), sensitive plant (*Mimosa pudica*), hilograss (*Paspalum conjugatum*), and honohono (*Commelina diffusa*). (Foote et al. 1972:26)

Soils of the Kokokahi Series are described as

> ….moderately well drained soils on talus slopes and alluvial fans…developed in colluvium and alluvium derived from basic igneous rock…. Used for dryland pasture and urban development. Vegetation is kiawe (*Prosopis paillida*), klu (*Acacia farnesiana*), koa-haole (*Leucaena glauca*), bermudagrass (*Cynodon dactylon*), and bristly foxtail (*Setaria verticulata*). (Foote et al. 1972:73)

Soils of the Keaau Series are described as

> …poorly drained soils … formed in alluvium weathered from basic igneous rock… used for growing" (Foote et al. 1972:64-65). Soils of the Mamala Series are described as "shallow, well drained soils that formed from alluvium deposited over coral limestone and consolidated calcareous sand..… used for irrigated sugarcane, orchards, truck crops and dryland pasture. Natural vegetation is kiawe (*Prosopis pallida*), koa-haole (*Leucaena glauca*), klu (*Acacia farnesiana*), bristly foxtail (*Setaria verticillata*), and fingergrass (*Chloris spp*.). (Foote et al. 1972:93)

The Jaucas Series

> ……consists of very excessively drained, calcareous soils …. on coastal plains adjacent to the ocean…developed in wind- and water-deposited sand from coral and seashells. The natural vegetation consists of kiawe (*Prosopis pallida*), koa-haole (*Leucaena glauca*), bristly foxtail (*Setaria verticulata*), bermudagrass (*Cynodon dactylon*), fingergrass (*Chloris spp*.) and Australian saltbush. (Foote et al. 1972:48)

Human burials have been found throughout the Hawaiian Islands within Jaucas sand deposits.

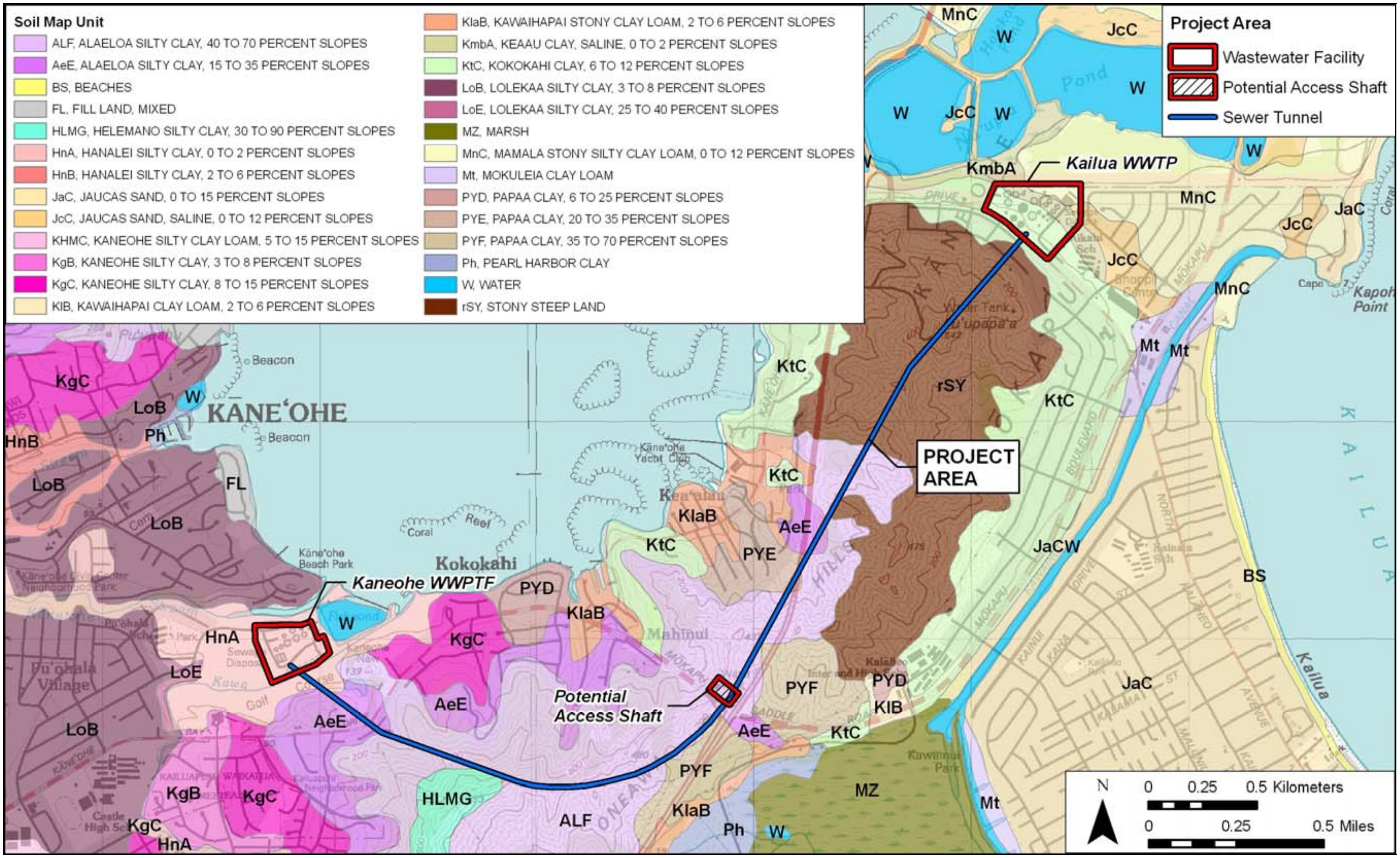

Figure 7. U.S. Geological Survey 7.5-Minute Series Topographic Map, Kāne‘ohe (1998) and Mōkapu Point (1998) quadrangles, with overlay of the Soil Survey of the State of Hawai‘i (Foote et al. 1972), indicating sediment types within the project area

1.3.2 Built Environment

Development within the project area consists of municipal wastewater infrastructure, including wastewater treatment plant structures and sewer pump stations. The subsurface portion of the project area is generally located beneath Oneawa Hills The surrounding area includes a golf course, yacht club, elementary schools, residential neighborhoods, Kāne‘ohe Bay Drive, Mōkapu Saddle Road, and the H-3 Interstate Highway.

1.3.3 Geotechnical Borings

Geotechnical boring testing was conducted within the intermediate tunnel access shaft portion of the project, in the vicinity of the existing water tank. Borings reached a depth of approximately 98 m (320.5 feet; see Appendix A). Testing results indicate the first 61 cm (2 feet) consists of silty gravel with cobbles. Below 61 cm (2 feet), gray dense basalt is present. Basalt with color and fracture variations extends to the bottom of the excavation (98 m below surface).

Section 2 Methods

2.1 Document Review

Historic and archival research included information obtained from the University of Hawai‘i at Mānoa’s Hamilton Library, the State Historic Preservation Division Library, the Hawai‘i State Archives, the State Land Survey Division, and the Archives of the Bishop Museum. Previous archaeological reports for the area were reviewed, as were historic maps and primary and secondary historical sources. Information on Land Commission Awards was accessed through Waihona ‘Āina Corporation’s Māhele Data Base (www.waihona.com).

This research provided the environmental, cultural, historic, and archaeological background for the project area. The sources studied were used to formulate a predictive model regarding the expected types and locations of historic properties in the project area.

2.2 Field Methods

The fieldwork component of the archaeological literature review and field inspection was conducted on August 24, 2010 by CSH archaeologist Randy Groza, M.A., and cultural specialist Joe Genz, Ph.D. under the general supervision of Hallett H. Hammatt, Ph.D. (principle investigator). The fieldwork required one person-day to complete.

In general, the purpose of the field inspection was to develop data on the nature, density, and distribution of archaeological sites within the project area, and also to develop information on the degree of difficulty that vegetation and terrain create for future archaeological studies. The field inspection consisted of a walk-through reconnaissance of the three portions of the project area. The spacing between the archaeologist and cultural specialist during the walk-through reconnaissance was generally 10 m.

Section 3 Traditional Background Research

3.1 Mythological and Traditional Accounts

The current project area is located within the Windward Oʻahu district of Koʻolaupoko, and is situated within the *ahupuaʻa* (land division) of Kāneʻohe.

Kāneʻohe is a large *ahupuaʻa* of approximately 8,000 acres, extending from the crest of the Koʻolau Range to the coast at Kāneʻohe Bay, and including most of the Mōkapu Peninsula. The project area extends beneath several *ʻili* (land sections within an *ahupuaʻa*) including Waikalua, Keana, Kalāheo, Mahinui, Paʻalae, Pūʻahuʻula, Mālaʻe, and ʻAikahi (Figure 8).

The meaning of the place name Kāneʻohe may come from *kāne* (man), which may be a reference to Kāne, the god of creation, and *ohe*, which means "bamboo." The word *kāne* has also been interpreted as "husband." The place name Kāneʻohe has been attributed to a story about a woman who compared her husband's cruelty to the cutting edge of a bamboo knife (Clark 2002). Kāneʻohe may also be derived from *ʻohe*, which is said to be one of the *kinolau* (body forms) of the god Kāne (Abbott 1992:15).

The following story relates to the origin of the of the place name Kāneʻohe:

> …in Kaneohe proper, the people learned a new use for the Ohe…In olden times anyone who did not conform to the way of life lived so industriously by the shore people, was called E-epa, or non-conformist. The Eʻepa were not actually "touched in the head", or lo-lo' [crazy], but just different. They liked to wander off by themselves and dwell among the mysteries of the upland forests where they listened to the music of Nature, and often became poets or musicians.
>
> Those upland reaches, all unexplored territory and sacred to the Spirits or Akua of Nature, where referred to as the Wao, or places of mystery. In order to keep children from wandering to the uplands, their elders told the little ones, "Do not go up there or the Bamboo Man may keep you. We would mourn your absence in loneliness. Remain at home and learn your useful duties."
>
> Hano-ihu…longed to explore. Puʻili…longed to accompany her playmate, Hano-ihu, when he wandered far. But, being more timid, she contented herself during the boy's absences and kept his secret of those upland trips he enjoyed.
>
> One sad day, Hano-ihu did not return. The people searched and could find not trace of the disobedient boy. Finally, the villagers decided the boy had died, and they told the other children that the Bamboo Man had taken the boy-wanderer.
>
> Puʻili…decided that he was not dead and she must search for him. Acting upon the thought, the little girl followed the direction often taken by the boy and was soon alone in the dark recesses of the forest lands of Wao, the Mysterious.
>
> She saw nothing to fear. Rather, she delighted in the beauty of the forests, the fragrance of the ferns and blossoms growing besides singing rills of sweet waters,

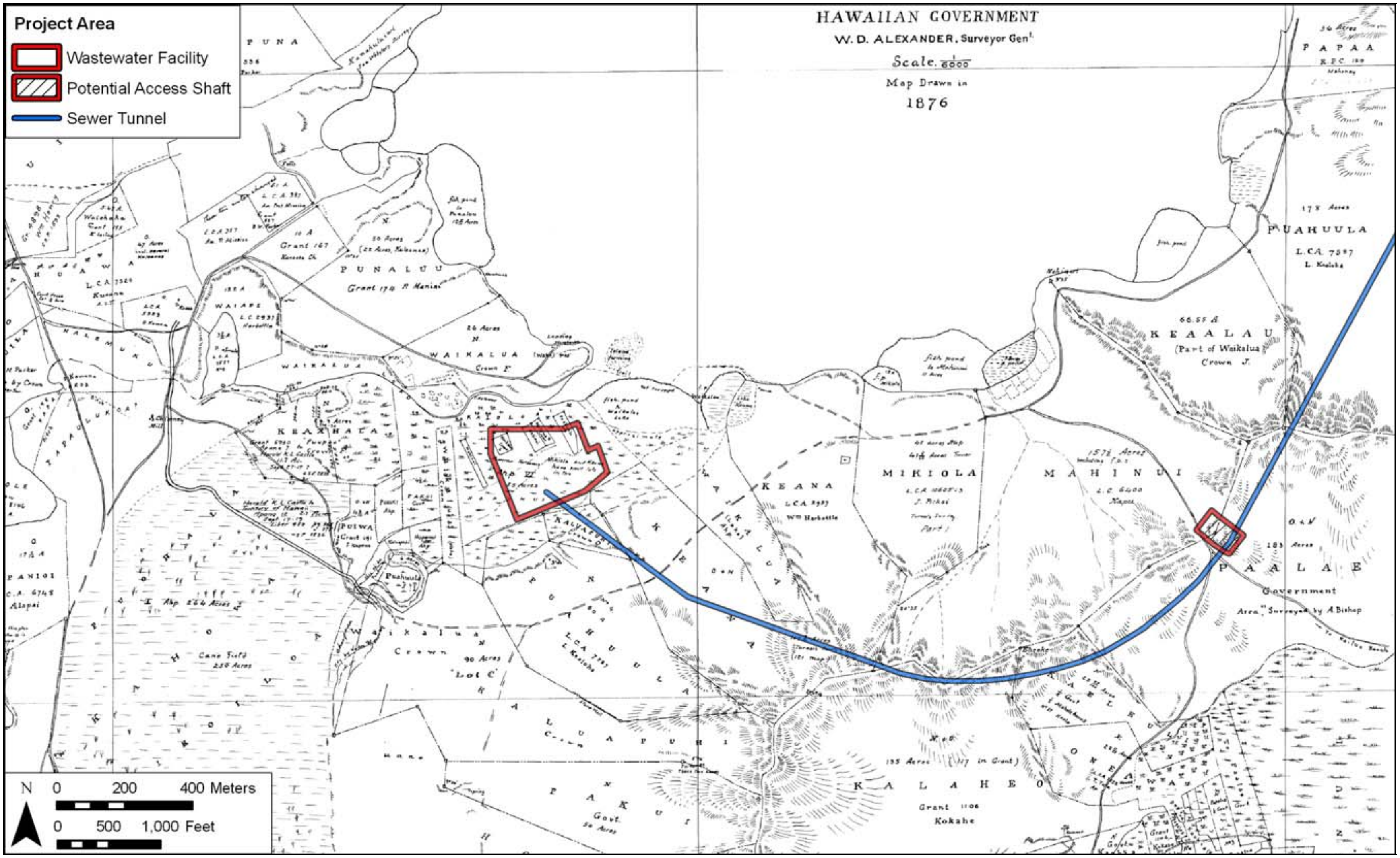

Figure 8. 1876 Map of Kaneohe and West Kailua (RM 585), C.J. Lyons surveyor, showing the location of the western portion of the project area

> and danced along happily to the whistling of the Wind Gods in the tree tops touching the blue sky far above.
>
> Soon she realized the whistling was not actually the Wind, for it had a bird-like note that repeated itself in a gentle rhythm. Also, she saw the bamboo moving in the breeze and heard how it rattled its branches. She found two lengths of a bamboo branch and, one in each hand, beat time on the two sticks while she followed the plaintive note calls.
>
> Before her…she saw her beloved playmate sitting on the bank. Beside him was a tall, thin man whose eyes watched the boy, while the child blew upon a bamboo length. The man's lean hands waved to the rhythm of the notes, and the girl went dancing toward the pair, keeping time with her pair of bamboo sticks.
>
> Hano-ihu and the tall man finished their melody, then praised the little Puʻili for joining them….She sat with them and learned that the man was Kaneʻohe, the Bamboo Man who, as a child, had followed the lure of Wao and had invented a bamboo flute. Kindly, the old man explained to the children how the art of creativity often is lost unless those inspired do follow the call. He told them, "Now we shall return to the village, for I have answered the call and you two little ones will be musicians like me. In honor of this occasion, I shall name the flute after you, my boy...we shall name the time-keeping sticks for her."
>
> Gaily, the three went down the forest trail of Wao the Inspiring. They were welcomed with feasting and joy. That is how we have the Ohe, or Bamboo, instruments today. The Hano-ihu or Nose flute; and the Puʻili, or notched Bamboo sticks; and the hula named for these gifts of Kaneʻohe, the Bamboo Man. (Paki 1972:29-30)

The following legend speaks to the importance of Kāneʻohe and the antiquity of Kawaʻewaʻe Heiau, approximately 1 kilometer southwest of the Kāneʻohe WWPTF. The word "kāwaʻewaʻe" literally refers to a type of stone or coral used for polishing canoes, or rubbing off pig bristles (Pukui and Elbert 1986). Thrum (1906:48) reports that Kawaʻewaʻe Heiau was erected in the beginning of the 12th century by the high chief ʻOlopana. Kawaʻewaʻe Heiau was said to have been constructed by *menehune*, the legendary race of small people who built structures by night (Fornander 1878:23).Windward Oʻahu is famous for legends of Kamapuaʻa, the half man, half pig demigod renowned for making mischief and for his masterful escapes from retribution for his chicken and taro thievery. One story centers on Kamapuaʻa and the Kawaʻewaʻe Heiau.

3.1.1 Waikalua ʻIli

Waikalua translates as "water of the *lua* fighter," or "water of the pit" (Pukui et al. 1974:222). The following account describes Waikalua as the setting of a mythological battle between the forces of good and evil:

> Over against this altar beside the chiming waters of Hiilaniwai on Mountain bright (Keahiakahoe), down by the sea, stood the pagan outfit of a dark sorcerer who plied his damnedest black arts for a fee. His establishment was near a fenced area of about thirty acres of wild rocky land called the "Waters of Slaughter" or

> Waters of Depression, “Wai-Kalua.” Here the old fellow did his wizardry and was supposed to counsel with evil spirits in the still dark night…
>
> Nearby this wizard’s hut, according to old timers, were two springs whose waters possessed supernatural power. Out of one, they said, came healing streams that imparted life and purity of soul to all who drank of it. The other poured forth a stream that carried spirits of demonical possession concealed in its waters, and spread eternal chaos and cruel death on every form of life it touched.
>
> As the story goes: Once the gods of the nether world and the spirits of the world of light engaged in furious battle over these springs. The Lights won and drove the subterraneous to an adjacent area or field at Waikalua. Here the defeated gods wreaked their rage for their defeat on every animate creature within reach, until, following another encounter with the gods of the upper world, they were driven to a place called “Milu” in the center of the earth. Later the scene of battle was fenced off from the surrounding holdings and named “The Pig Pen”--“Ka-Pa-Puaa.” (Parker n.d.:7-8, cited in Sterling and Summers 1978:209)

The legend of La‘amaikahiki is associated with Nāoneala‘a, located on the Kāne‘ohe Bay shoreline within Waikalua ‘Ili. The legend describes the chief La‘a’s arrival on O‘ahu from Kahiki (the ancestral homeland of Hawaiians), at Nāoneala‘a.

> La‘a, that is, La‘a-mai-Kahiki was so named for his coming from Kahiki. After the death of Olopana, the kingdom was inherited by La‘a, and he heard from Kila and others that Hawaii was a fertile land, and that the people were great farmers and keepers of fish in fish ponds. Oahu was the richest of all, so La‘a became determined to come here to Hawaii.
>
> There was a man at Hanauma named Ha‘ikamalama. When he heard sounds from the sea, he wondered what it was. It was the sound of the big and little drum, therefore he thumped the rythmn on his chest with the tips of his fingers…The sound seemed to come from the sea on the Koolau side, so he sailed to Makapu‘u. He saw them going by on the ocean so he went by land until he saw the canoe heading toward Ka-waha-o-ka-Mano. He guessed that they were going to Kaneohe in Koolau-poko. When the canoe reached Wai hau palua, he ran to the shore, with his fingers beating the rythmn and he chanting the chant to Kupa.
>
> When La‘a and the men on the canoe noticed this, they were astonished. He knew their names through their playing of the kaeke [drum]. La‘a threw out some sand as a resting place for the canoes. This place is now called Na-one-a-La‘a (La‘a’s sands.) It is in Kaneohe. (Kamakau 1867, cited in Sterling and Summers 1978:209-210)

It is said that La‘a brought with him from Kahiki the hula and *pahu* drums, components of a new religion, that had been previously unknown to the islands (Landgraf 1994:116). Nāoneala‘a, was “tapu [forbidden] to the commoner when alii lived there” (McAllister 1933:178).

Nāoneala‘a was also the site of a meeting to end a war between the chiefs Alapa‘i and Peleioholani, and their warriors:

> So it was that Pele-io-holani and Alapaʻi met at Naonealaʻa in Kaneʻohe, Koʻolaupoko, on Kaʻelo 13, 1737, corresponding to our January. The two hosts met, splendidly dressed in cloaks of bird feathers and in helmet-shaped head coverings beautifully decorated with feathers of birds. Red feather cloaks were to be seen on all sides, both chiefs were attired in a way to inspire admiration and awe, and the day was one of rejoicing as that of the ending of a dreadful conflict. The canoes were lined up from Kiʻi at Mokapu to Naonealaʻa and there on the shore line they remained, Alapaʻi alone going on shore. The chiefs of Oahu and Kauaʻi, the fighting men, and the country people remained inland, the chief Pele-io-holani advancing alone. Between the two chiefs stood the counselor Na-ʻili, who first addressed Pele-io-holani saying, "When you and Alapaʻi meet, if he embraces and kisses you let Alapaʻi put his arms below yours, lest he gain the victory over you." This is to this day the practice of the bone-breaking wrestlers at Kapua and at Naonealaʻa. Alapaʻi declared an end of war, with all things as they were before, the chiefs of Maui and Molokai to be at peace with those of Oahu and Kauaʻi, so also those of Hawaii. Thus ended the meeting of Pele-io-holani with Alapaʻi. (Kamakau 1992:72)

3.1.2 Keana ʻIli

Keana translates as "the cave" (Pukui et al. 1974:103). The following account describes a spring, named Kinikailua-Manokaneohe, located in the *ʻili* of Keana, near the Kāneʻohe Bay shoreline:

> This story comes through Judge Kellett who says that an old resident of Kaneohe told it to him. Down by the shore of the bay (the strip of land now owned by the YWCA) there was and is a spring right amidst the banana grove just before you reach Kokokahi. This spring was supposed to have medicinal virtue and people from all over Koolau came there to drink for various ailments. They were a war-like people in the olden days and each district had its chief who warred on his neighboring ruler on the slightest provocation. The kahunas over at Kokokahi (Keana) sided with the Kaneohe people and had no love for those of Kailua. Hearing that a considerable detachment from Kailua were coming to the spring, they prepared a very inhospitable welcome. They poured down into the spring a quantity of this poison and it worked. The destruction was considerable, "ma-no" (literally 4,000). Now the kahunas neglected to inform their own people--those of Kaneohe--of the libation they had poured out and all unsuspecting the Kaneohe people came over in large numbers for the medicinal drink. Many, many of them died. "Ki-ni" (literally 40,000). (The Friend 1937:150, cited in Sterling and Summers 1978:211)

3.1.3 Kalāheo, Mahinui, Paʻalae, Pūʻahuʻula, Mālaʻe, and ʻAikahi ʻIli

Little information specific to the remaining *ʻili* in the vicinity of the current project area is available. Kalāheo translates as "proud day" (Pukui et al. 1974:73). Mahinui translates as "great champion," with the land area named for a legendary hero (Pukui et al. 1974:138). Mahinui was known as a "regular place of rest for the travelers, called oioina by the ancients" (*Hoku o*

Hawaiʻi 1925, cited in Sterling and Summers 1978:211). No translation was found for Paʻalae. Pūʻahuʻula translates as "the feather-cloak spring" (Pukui et al. 1974:100). Mālaʻe translates as "clear" (Pukui et al. 1974:143). ʻAikahi translates as "eat scrap (as the sides of a *poi* bowl; thus, to eat all)" (Pukui et al. 1974:7).

3.1.4 Mōkapu Peninsula

The Mōkapu Peninsula is associated with the creation of the first person.

> There on the eastern flank of Mololani, facing the sunrise and near the shoreline, the soil is red earth mingled with very dark bluish black earth. There is where the first man was made. That place was called in the old times Kahakahakea, but in these days it is Pahuna. There Kane drew the image of a man in the soil; he drew the image in the soil after the likeness of the Gods, with head, body, arms, legs, just like themselves in form. When the image was drawn in the soil Kanaloa said, "You will not get your man; you have not the power; I am the person who has power." Kanaloa therefore made an image of earth just like Kane's image. Kane and his companions said, "Let your earth become man," but no man came forth; his dirt figure of a man remained lying there and it turned into stone. Kane then said to his fellow gods, Ku and Lono, "Listen, you two, to my words and to the words I speak in answer and do you two preserve them and listen." Then Kane said, "Come to life," "Live," responded Ku and Lono "Come to life," said Kane, "Live," said Ku and Lono. Then the dirt became a living man.
>
> When the first man was made, the gods took the house name Hale-kou (House of kou wood) which they had made, and there the first man lived; but the woman was not made. The man observed how his shadow followed his body going outside the house and coming into the house, and he ran to the beach of Nuʻupia and Oneawa and found to his surprise that his shadow stuck to him. Now when this man had fallen asleep, as he awakened suddenly a pretty woman was at his side and he thought it was his shadow that was sticking to his side and that God had changed his shadow into a wife for him. He therefore gave her the name of Keakahulilani (the shadow made of heaven). This means that God had turned the soil of the earth into man. In various genealogies we often find other names given to this man; in some genealogies he is named Kumuhonua, in others Kulipo, in others again, Kumuuli, and in some Hulihana. (Kamakau, Moolelo o Hawaii (circa 1840), Chap I, in Sterling and Summers 1978:216)

The Mōkapu Peninsula and the waters surrounding it were once held by Hawaiian royalty:

> Here, in the 16th century, the royal palace of King Peleiholani was the scene of gay court pageantry. His impressive estate sat in the area adjacent to Nuupia fish pond, and bordering Kaneohe Bay.
>
> In the following century, Kamehameha the Great (the Lonely One) selected the site for use as a royal meeting place with his aliis. It became "the sacred land of Kamehameha," from whence the peninsula got its name. The name was originally Moku-kapu, and is derived from two Hawaiian words. Moku is a small island or peninsula, and kapu means sacred or keep out…

> The sea around Mokapu peninsula was tabu in olden days. The right to fish was given only to the high chiefs and servants of the King.
>
> These fishing grounds were called koʻa. Fishing was confined to certain types of fish native to certain sections of the ocean. Persons were assigned to areas with the task of feeding the fish two or three times a week. Seaweed would be gathered up in baskets and taken to the fishing grounds in canoes. It was hoped that by this treatment the fish would remain in the area, and be available for consumption when needed.
>
> When an important person and his retinue were expected or a feast planned, selected fishermen would carry specially prepared food to the grounds. The food was concoction of seaweed mixed with crushed candle nuts [kukui], a type of nut that has an extremely laxative effect. Two days before the occasion, the fish were fed the mixture with the result they expelled all food matter from their systems.
>
> The next day, fishermen threw their nets and baited hooks over the sides of their canoes and were rewarded with schools of hungry fish. The fish were so hungry that placing a finger in the water was an invitation to having it bitten. This type of fishing is as old to the Hawaiians as their culture. (Fiddler 1956:2)

Fiddler (1956:3-4) notes that

> Mokapu peninsula was sub-divided into six sections. The tip of the left lobe of the peninsula was called Mokapu and was in the Heeia Section, while Heleloa, Kuwaaohe, Ulupau, Halekou-Kaluapuhi, and Nuupia, rested in the Kaneohe district…..Nuupia was considered to be a separate piece of property and did not automatically become assigned with the adjacent land. It was assigned individually like the ili.

Fiddler (1956:13) continues, explaining that Kaluapuhi was a large fishpond that was once located within the inland extent of the Mōkapu Peninsula:

> Today, it is referred to as Nuupia fish pond, but in the earlier days of the century, the area was covered by 297 acres of water, an area which embraced three fish ponds, Halekou and Nuupia to the left of the present road, and Kaluapuhi on the right.
>
> Journeying further back into history reveals the entire area was once the site of one gigantic fish pond known as Kaluapuhi. It was the property, of royalty who resided on its shores, and was strictly tabu to all others.
>
> Halekou and Nuupia are said to be enlargements of this original pond. Legend has the watery expanse of Kaluapuhi being guarded by an eel which, in Hawaiian lore, was a mermaid who watched over the royal fish ponds. It formed the pond by burrowing its way across the mile-wide neck of Mokapu, seeking a shorter passage from Kaneohe Bay to Kailua Bay. The eel was singled out as the guardian of fishponds in Hawaii because it was considered as having the inherent and natural right to perform this function. (Fiddler 1956:13)

The Nu‘upia fishpond, located just north of the Kailua WWTP (Figure 9), was named for the starch trees that once grew in the vicinity:

> At one time, Nuupia fish pond was completely surrounded by groves of starch trees, from which it derived its name. These trees were actually huge plants with large leaves, and bore a large bulbous, potato-like growth, about the size of a watermelon. The juice from this plant was extracted and used for the mothers of breast-fed infants. It stimulated the flow of milk from the mother’s breasts. The remainder was used in the making of starch. (Fiddler 1956:14)

Fornander (in Sterling and Summers 1978:214) also relates that:

> Nuupia was the father and Halekou the mother of Puniakaia. The parents of Puniakaia were of the royal blood of Koolauloa and Koolaupolo…
>
> Halekou after this went out accompanied by the chiefs, until they came to the pool where Uhumakaikai made its home. (Uhumakaikai was the parent of all fishes.) This pool is at Nuupia to this day.

PHRI’s (1995:26) research details Nu‘upia Pond oral histories collected in 1939 by Kenneth Emory and Mary Pukui for the Bishop Museum:

> Nuupia pond is a very large one and on one side is a smaller pond used for salt evaporation. This pond is called Kapoho. The tallest peak on Mokapu is called Puu-o-Kaha’i. A man by the name came to Mokapu from Lahaina, Maui, in the olden days. Before he died, he asked to be buried there. His last resting place is known as Kahai’s hill.
>
> Below at the hill stands a house at a place called Ka-lua-puhi or Eel’s pit. This is a hole where many eels were caught. When foul smelling fish were let down here, the eels came up and were caught. She used to catch eels here in her youth. The land back of Nuupia is called Malaea. (HEN I:1314-1318 in PHRI 1995:26)

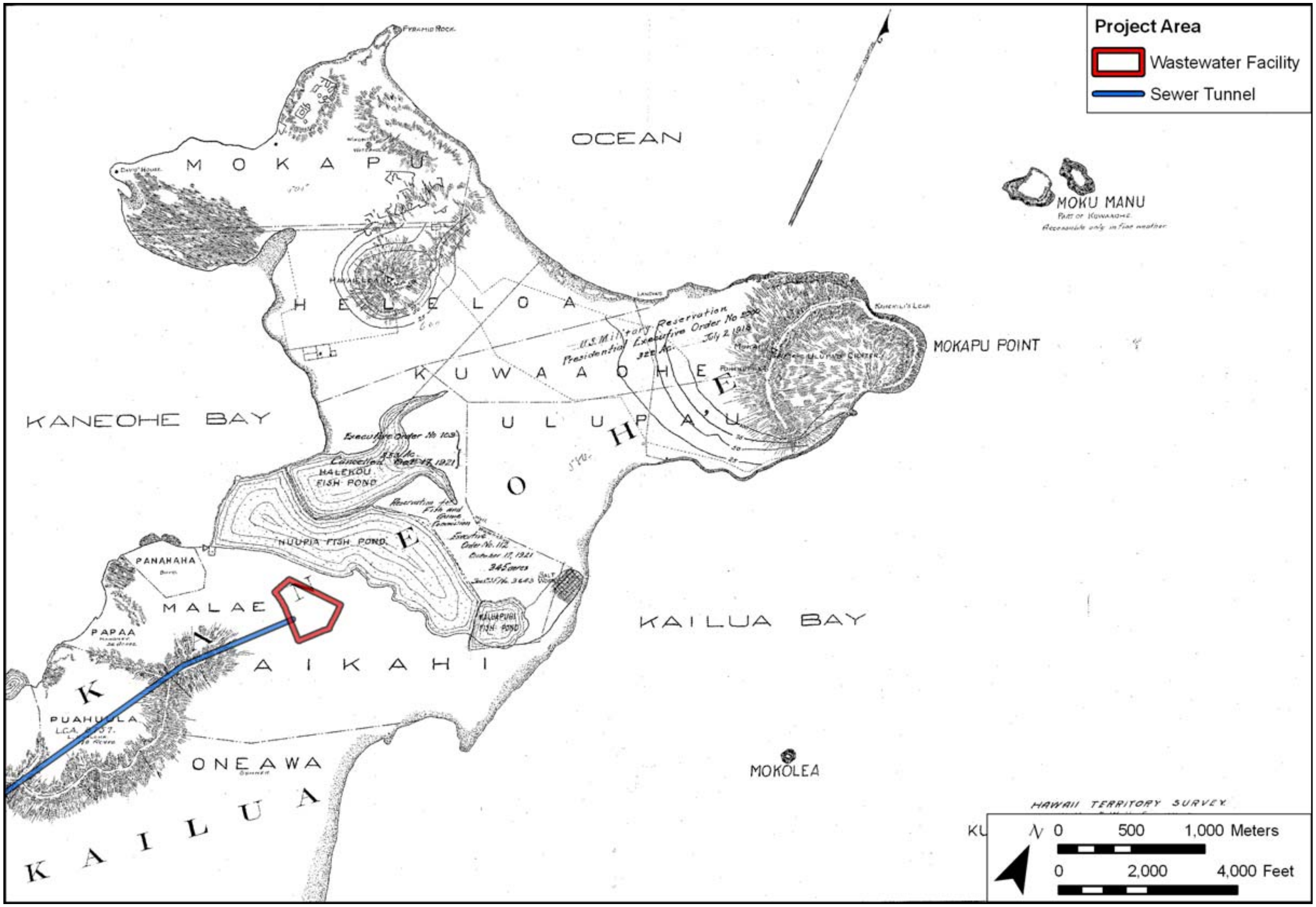

Figure 9. 1914 Map of Kuwaaohe and Halekou-Kauapuhi Government Lands (Plat 2044), W.A. Wall surveyor, showing the location of Nu‘upia Fish Pond in relation to the Kailua WWTP portion of the project area

3.2 Historical Background

3.2.1 Pre-Contact Period

The *ahupua‘a* of Kāne‘ohe was prosperous and densely populated in pre-contact times. With fresh water from *mauka* springs and perennial streams, as well as a well-developed fishpond system, Kāne‘ohe was rich in agricultural and aquacultural productivity, and one of the primary population centers on O‘ahu:

> …along the windward coast, beginning with Waikane and continuing through Waiahole, Ka‘alaea, Kahalu‘u, He‘eia, and Kane‘ohe, were broad valley bottoms and flatlands between the mountains and the sea which, taken all together, represent the most extensive wet-taro area on Oahu. These taro lands were irrigated from both streams and springs. Along the shores thereabouts were also some very large salt-water fishponds. This whole region must have supported a dense population…
>
> The area that included what is now Kane‘ohe and Kailua, which was rich in fishponds and tillable lands, was the seat of the ruling chiefs of Ko‘olaupoko (Short Ko‘olau) which was the southern portion of the windward coast. (Handy and Handy 1972:271-272)

Nathaniel Portlock, captain of the British vessel *King George*, provided the following description of Kāne‘ohe circa the late 1780s, shortly after western contact:

> The [Kāne‘ohe] bay all round has a very beautiful appearance, the low land and valleys being in a high state of cultivation, and crowded with plantations of taro, sweet potatoes, sugar cane, etc., interspersed with a great number of coconut trees, which renders the prospect truly delightful. (Portlock 1789:74, cited in Handy and Handy 1972:455)

Pre-contact land use in Kāne‘ohe consisted primarily of plantations of *kalo* (taro), bananas, sweet potatoes, and coconut trees, as well as groves of *hala* (pandanus; used for making household furnishings such as mats) and *wauke* (paper mulberry; used for making cloth) (Handy and Handy 1972:456). Handy and Handy (1972) describe how the natural environment of Kāne‘ohe was conducive to development of a complex agricultural system:

> The broken topography of Kaneohe arranges the areas of flatland like chains of pockets connecting along its stream channels between hills. On the north side of the *ahupua‘a* near the boundary of He‘eia, Kea‘ahala Stream flows into Kalimukele, coming out of He‘eia. Some of the best *lo‘i* still in use in 1953, *mauka* of the highway, were irrigated by Kea‘ahala, and a large old *lo‘i* system once extended downstream below the highway. An elaborate system of water rights prevailed in ancient times throughout these sections irrigated from Kea‘ahala.
>
> The other streams—Wailele (formerly Pani‘ohelele), Hi‘ilaniwai, Kahuaiki, Mamalahoa—likewise watered many taro *lo‘i*… Hi‘ilaniwai is a very long stream, with its origin in the slopes that drain Pu‘u Lanihuli, the peak that flanks

> the northern side of the Nu'uanu Pali road and the southern boundary of Kaneohe. In fact all of the *ahupua‘a* is like a vast green amphitheater below the serrated sheer cliffs that extend from Pu‘u Lanihuli northward to Ha‘iku Valley and known as the Ke-ahi-a-Kahoe (Fires-of-Kahoe) Cliffs. As the ground rises steeply from the stream beds along their upper courses, there is little evidence of systematic terracing observable in these areas, as might have been expected. The lowland areas were so extensive that evidently the more laborious terracing of the interior slopes was not regarded by the early Hawaiians as necessary.
>
> The kula lands between the streams were planted in pandanus, *wauke*, bananas, and sweet potatoes. *Kalo malo‘o* (dry-taro) was not planted here. The number of names of *‘ili* and *kuleana* on *kula* lands along the Hi‘ilaniwai and its tributaries, however, indicates intensive cultivation of products other than taro, and the abundant rains sweeping down from the cliffs made such cultivation profitable. (Handy and Handy 1972:455-456)

In general, lands suitable for development of *lo‘i* (irrigated terraces) were located along main streams and coastal lowlands (Devaney et al. 1982:36) such as Kāne‘ohe WWPTF. *Lo‘i* development required diversion of stream water for irrigation, and construction of terraces to pond the water:

> …this [taro] root, the principal food of the inhabitants of these Islands, grows only in low, well watered places, and where no such places are provided by nature the natives frequently with great difficulty make excavations so that water may collect in these basins which frequently are several ells deep. (Billie Ms.:131, cited in Devaney et al. 1982:35-36)

In addition to the extensive agricultural cultivation, the people of Kāne‘ohe Bay sought the bountiful marine resources:

> …the sea adjoining an *ahupua‘a* [Kāne‘ohe] was considered to be an extension of that *ahupua‘a*; its resources were shared by the chief and all of the tenants (*hoa‘āina*) living in the *ahupua‘a*. Access to the sea was part of the *mauka-makai* concept, which made the products of land and sea available to the people living in the *ahupua‘a.* (Devaney et al. 1982:135)

Just as the land-based resources of the *ahupua‘a* were managed through subdivision into *‘ili*, the marine resources of the *ahupua‘a* were also partitioned, with discreet fisheries associated with the *‘ili* along the Kāne‘ohe Bay coast (see Figure 8). In addition to shoreline and offshore fishing, fishponds were constructed along the Kāne‘ohe Bay shoreline to provide regular supplies of fish to the inhabitants of the *ahupua‘a*:

> Shoreline fishing is highly susceptible to the vagaries of weather and surf conditions. With walled fishponds, Hawaiians provided for themselves a regular supply of fish when other types of fishing were not possible or yielded an insufficient supply. The fringing reefs along the shoreline of Kaneohe Bay were ideal for the type of walled fishponds that extended out from the land.

> Mullett, one of the world's most important food fishes, was the most common species raised by Hawaiians in their fishponds; *awa* (milkfish) followed a close second. (Devaney et al. 1982:140)

Several fishponds were located in the vicinity of the current project area (see Figure 8), including (from west to east): Waikalua Loko (just north of Kāne‘ohe WWPTF), Waikala‘a, Keana, Mikiola, Kaluoa, Mahinui, Kea‘alau, Hanalua, Pāpa‘a, and Nu‘upia (just north of Kailua WWTP) (McAllister 1933; Devaney et al. 1982:147). Kamakau relates the number of fishponds in an area to the population that would have been necessary for their construction:

> The making of walls (*kuapa*) of the shore ponds was heavy work, and required the labor of more than ten thousand men…
>
> Many *loko kuapa* were made on Oahu, Molokai and Kauai, and a few on Hawaii and Maui. This shows how numerous the population must have been in the old days, and how they must have kept the peace, for how could they have worked together in unity and make these walls if they had been frequently at war…? If they did not eat the fruit of their efforts how could they have let the *awa* fish grow to a fathom in length; the *‘anae* to an *iwilei*, yard…? (Kamakau 1976:47, cited in Devaney et al. 1982:142)

3.2.2 Early Historic Period to Mid 1800s

In 1795 Kamehameha, at that time the Hawai‘i Island chief, invaded O‘ahu to secure control of the islands of O‘ahu, Moloka‘i, and Lāna‘i after his successful conquest of Maui. The O‘ahu Island chief Kalanikūpule, Moloka‘i Island chief Ka‘iana, and their forces met Kamehameha's army in the valley of Nu‘uanu. The following account describes the final stages of the battle at the Nu‘uanu Pali, the knife-edge ridge along the Ko‘olau Range separating Nu‘uanu from Kāne‘ohe Ahupua‘a:

> The forces of Kamehameha charged; in the onslaught many of the Oahuans were slain, and the rest pursued with great slaughter until they were driven to the end of the valley, which terminates in a precipice of six hundred feet, nearly perpendicular height, forming a bold and narrow gorge between two forest-clad mountains. A few made their escape; some were driven headlong over its brink, and tumbled, mangled and lifeless corpses, on the rocks and trees beneath; others fought with desperation and met a warrior's death, among whom was Kalanikupule, who gallantly contested his inheritance to the last. (Jarves 1872:85)

Kamakau (1992:172) offers an alternate fate for Kalanikūpule, noting that he escaped to the mountains with some of his men for several months, but was later discovered and sacrificed to Kamehameha's war god Kūkā‘ilimoku.

Following the conquest of O‘ahu by Kamehameha, the lands of the island were divided between Kamehameha and his followers. Likely due to its agricultural and fishery productivity, Kāne‘ohe Ahupua‘a was seen as the "most valuable part" of the Ko‘olaupoko District (Kamakau 1992:303). Kāne‘ohe Ahupua‘a was retained by Kamehameha as his personal property, and was later inherited by his sons Liholiho and Kauikeaouli, Kamehameha II and III (Kame‘eleihiwa 1992:233).

In the early 1800s, there were three primary routes to Windward O‘ahu from the growing town of Honolulu. These were:

> …around the island by canoe; through Kalihi Valley and over the pali by ropes and ladders (Graham 1826:142); and over the Nuuanu Pali, the easiest, quickest, and most direct route. (Devaney et al. 1982:163)

The trail over the Nu‘uanu Pali was a heavily utilized transportation corridor since it allowed the people of Windward O‘ahu to bring their agricultural products to Honolulu for sale. The Reverend Reuben Tinker described his trip over the Nu‘uanu Pali in 1831:

> It seemed to me a sublime pass, yet almost too fearful to be enjoyed, for though not unaccustomed to hills, and the ups and downs of life, I suffered from apprehension lest I should fall from the rocky steep. I took off my shoes and by setting my feet in the crevices of the rocks, I worked myself along, assisted by a native, who saw nothing to wonder at but my awkwardness and fear on passing this grand highway, though to them common. The natives do not think it is either wonderful or difficult; it is the main road connecting the opposite sides of the island, and men and women are going up and down with their ordinary burdens on their shoulders, and in their arms, such as bundles of taro and potatoes, calabashes of poi, fowls, goats and pigs. Mothers were passing along the most precipitous places with their children on their shoulders, as careless of danger as if they were on a level plain… (Tinker 1901:88, cited in Sterling and Summers 1978:225)

Traditional agricultural practices, including wetland taro cultivation, continued to dominate land use in Kāne‘ohe in the early years following western contact, although to a lesser degree. Introduced diseases dramatically reduced the native Hawaiian population to a fraction of its pre-contact level:

> In the reign of Kamehameha, from the time I was born until I was nine years old, the pestilence (*mai ahulau*) visited the Hawaiian Islands, and the majority (*ka pau nui ana*) of the people from Hawaii to Niihau died. (Malo 1839:125, cited in Devaney et al. 1982:8)

Agricultural lands were subsequently abandoned due to the decrease in population. In 1828, the missionary Levi Chamberlain embarked on a tour around the island of O‘ahu to determine the progress occurring at schools established to educate native Hawaiians. During his tour, Chamberlain (1828:26) made observations of the landscape and people around the island commenting on the "present neglected state" of formerly cultivated agricultural lands:

> [The natives] ascribed it to the decrease in population. There have been two seasons of destructive sickness, both within the period of thirty years, by which, according to the account of the natives, more than one half of the population of the island was swept away. The united testimony of all, of whom I have ever made any inquiry respecting the sickness, has been, that "Greater was the number of the dead than of the living."
>
> …it may, I think, be safely asserted, that since the discovery of these islands by Cap. Cook there has been a decrease of population, by desolating wars, the

ravages of disease and other causes, of at least one half of the number of inhabitants that might have been fairly estimated, at the time that celebrated voyager last visited these islands. (Chamberlain 1828:26)

3.2.3 The Māhele (Land Divisions)

In 1845, the Board of Commissioners to Quiet Land Titles, also called the Land Commission, was established "for the investigation and final ascertainment or rejection of all claims of private individuals, whether natives or foreigners, to any landed property" (Chinen 1985:8). This led to the Māhele, the division of lands between the king of Hawaii, the *ali'i* (chiefs), and the common people, which introduced the concept of private property into the Hawaiian society. In 1848, Kamehameha III divided the land into four categories: certain lands to be reserved for himself and the royal house were known as Crown Lands; lands set aside to generate revenue for the government were known as Government Lands; lands claimed by *ali'i* and their *konohiki* (supervisors) were called Konohiki Lands; and habitation and agricultural plots claimed by the common people were called *kuleana* (Chinen 1985:8-15).

Kamehameha III inherited Kāne'ohe, and retained the bulk of the *ahupua'a* during the Māhele. Following the death of Kamehameha III in 1854, his wife, Queen Kalama (Hakaleleponi), retained their Kāne'ohe lands (Land Commission Award [LCA] 4452). Along with the *ahupua'a* of Kailua and Hakipu'u, Kāne'ohe was seen as "her most valuable *'Āina*…all in the fertile, well-watered district of Ko'olaupoko" (Kame'eleihiwa 1992:264). Several *'ili* in Kāne'ohe were subsequently awarded as Konohiki Lands to the *ali'i*, and those with close ties to the royal family. The title to the *'ili* typically included ownership of the *'ili's* fishpond and offshore fishing rights (Devaney et al. 1982:143). High-ranking *ali'i* were awarded entire *'ili*, while lesser *konohiki* were awarded half of an *'ili* each (Kame'eleihiwa 1992:269, 279). In addition to Queen Kalama, 14 *konohiki* LCAs were awarded for Kāne'ohe lands (Kelly 1976:7).

An 1876 map of Kāne'ohe (see Figure 8) shows the Crown Lands, Government Lands, and large LCAs distributed to the *ali'i* and *konohiki* in the vicinity of the current project area. The *'ili* of Waikalua was designated as Crown Lands, and the *'ili* of Pa'alae was designated as Government Lands. The *'ili* of Malae and 'Aikahi were awarded to Queen Kalama (LCA 4452:13). No land use information was provided in the land commission testimony. Mahinui 'Ili was awarded to Kapu (LCA 6400), and Puahu'ula 'Ili was awarded to Luisa Kealoha (LCA 7587). No land use information was provided in the land commission testimony for these awards. The *'ili* of Kalāheo was designated as Grant 1106 to Kokoahe. No land use information was provided in the grant testimony.

William Harbottle, a part-Hawaiian with close ties to the King, was awarded the *'ili* of Keana (LCA 2937). Testimony associated with Harbottle's claim for Keana 'Ili indicated he had received the land from Kamehameha III (N.R. Vol. 3: 701-702), with land uses including *lo'i* and *kula*. Testimony also indicated the presence of sand dunes along the shoreline, and that Harbottle lived on the land since 1833. The 1876 map of Kāne'ohe (see Figure 8) indicates a house near the shore, along with a fishpond ("Loko Keana").

The lands awarded as Crown Lands and Konohiki Lands, as well as lands designated as Government Lands, were "subject to the rights of native tenants" (Chinen 1958). The Kuleana Act of 1850 "authorized the Land Commission to award fee simple titles to all native tenants who occupied and improved any portion of Crown, Government, or Konohiki Lands" (Chinen 1958:29). Surveyor C.J. Lyons stated:

> Small tenants were permitted to acquire a full title to the lands which they had been improving for their own use…for it was the labor of these people and their ancestors that had made the land what it was. (Lyons 1875:127, cited in Devaney et al. 1982:22)

One hundred seventeen *kuleana* land claims were awarded in Kāneʻohe Ahupuaʻa, with the average award being approximately 2.4 acres (Kelly 1976:8). Testimonies associated with the Land Commission Awards (LCA) indicated the primary land use for the claimed lands was *loʻi*, irrigated fields used for cultivating taro (Kelly 1976:8). Testimonies also indicated land uses such as: growing breadfruit, coconut, *hala* (*Pandanus tectorius*), gourds, melons, *ʻape* (*Alocasia macrorrhiza*), *pia* (*Tacca leontopetaloides*), pineapple, and banana; salt ponds; and *kula* (pasture) for raising animals (Devaney et al. 1982:23). The 19 LCAs in the vicinity of the current project area are listed in Table 1 and indicated on Figure 10. Note that multiple *āpana* [parcels] for two LCAs (26282, 4486) are within the project area. LCA testimonies indicate these land claims were primarily for *loʻi*, house lots, and fishponds.

Coulter's (1931) population density estimates for 1853 (Figure 11) show that approximately 700 people lived near the coast of Kāneʻohe Ahupuaʻa, which was one of the more densely populated areas on Oʻahu. While both the Kāneʻohe WWPTF and the Kailua WWTP vicinities are shown as densely populated, no *kuleana* land claims were awarded near Kailua WWTP. The Nuʻupia Fishponds in the vicinity of Kailua WWTP are the likely explanation for the concentrated population.

The Kāneʻohe WWPTF portion of the project area is located in a low-lying area between Kāneʻohe and Kawa Streams, immediately inland of the Waikalua Loko Fishpond. This well-watered coastal flat, known as the "Waikalua Swamp," was an area of intensive traditional agricultural development (i.e. *loʻi*). An 1896 map (Figure 12), shows the dense cluster of LCAs in the "Waikalua Swamp" area. As the "Waikalua Swamp" area was such a productive locale, the less productive *ʻili* in the vicinity (i.e. *ʻili* without reliable sources of fresh water) had *lele* (land parcels separate from, but under the jurisdiction of, the main *ʻili* lands) in the "Waikalua Swamp." As such, claimants that may have resided in other *ʻili* in the Kāneʻohe Bay area tended to have their *loʻi* in the "Waikalua Swamp" area.

Table 1. Land Commission Awards (LCA) Within Kāne‘ohe WWPTF

LCA #	*‘Ili*	Claimant	Land Use	Awarded
1899	Pu‘uiki, Kaluapuhi, Pakui	Opunui	*Lo‘i*, house lot	3 *‘āpana*
1995	Punalu‘u	Nuole	*Lo‘i*, house lot	2*‘āpana*
2060	Pu‘uiki, Waikalua	Kaulakoa	*Lo‘i*, house lot	4 *‘āpana*
2444	Kalokoai	Keawekukahi	*Lo‘i*, fishponds	3 *‘āpana*
2628	Waikalua	Paele	*Lo‘i*, house lot, fishpond	3 *‘āpana*
2941	Opu‘upao, Kapu, Pua‘ai, Punalu‘u	Kekalei	*Lo‘i*, house lot	3 *‘āpana*
3344	Keana, Mikiola, Punalu‘u	Naiwieha	*Lo‘i*, house lot, *hala* trees	1 *‘āpana*
3692 B	Waikalua	Keaka	*Lo‘i*, house lot	4 *‘āpana*
3706 B	Kaluapuhi, Keana	Nawai	*Lo‘i*	1 *‘āpana*
3707 B	Kaloioai	Keawe	*Lo‘i*	1 *‘āpana*
4217	Malae, Waikalua	Kaula	*Lo‘i*, house lot, *kula*, fishpond	4 *‘āpana*
4481	Keana, Waikalua	Honuaiwa	*Lo‘i*, house lot, *kula*	4 *‘āpana*
4486	Mahinui	Kane	*Lo‘i*	4 *‘āpana*
8892	Keana, Pu‘uiki, Waikalua	Kumoenahulu	*Lo‘i*, house lot	2 *‘āpana*
9639	Waikalua, Keana, Punalu‘u	Kaniau	*Lo‘i*, house lot	4 *‘āpana*
10202	Pu‘upao, Mikiola	Makakea	*Lo‘i*, house lot, fishpond	3 *āpana*
10605*	Mikiola	Iona Pi‘ikoi	Not stated	*‘Ili* of Mikiola
10668 B	Mahinui, Mikiola	O‘opa	*Lo‘i*, house lot, *kula*, fishpond	1 *‘āpana*
10739	Kalokoiai	Pa	*Lo‘i*, house lot	1 *‘āpana*

* - *Konohiki* Award

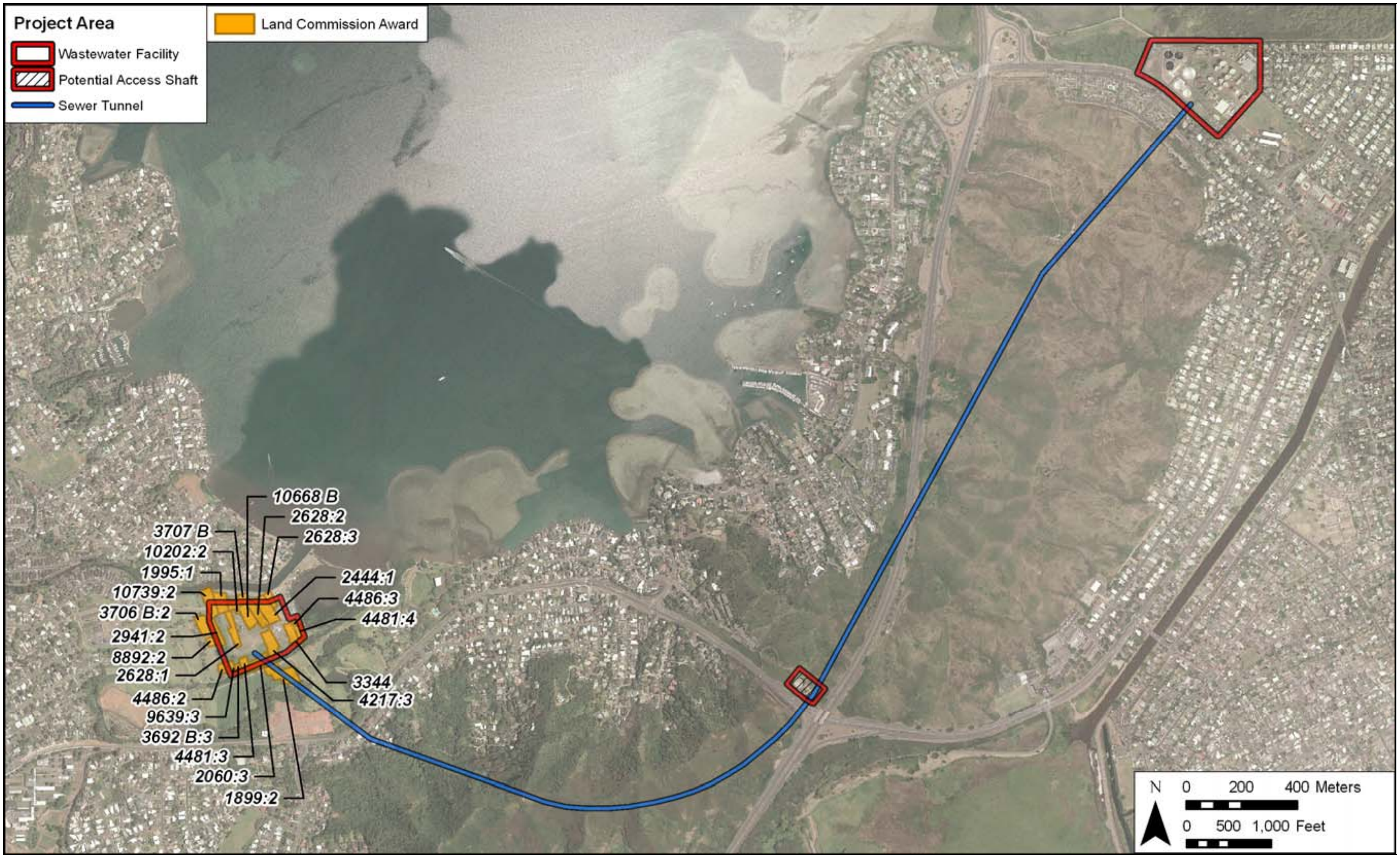

Figure 10. Areal map showing locations of LCAs within project area

Figure 11. 1853 population density estimates; each symbol represents 50 people (Coulter 1931)

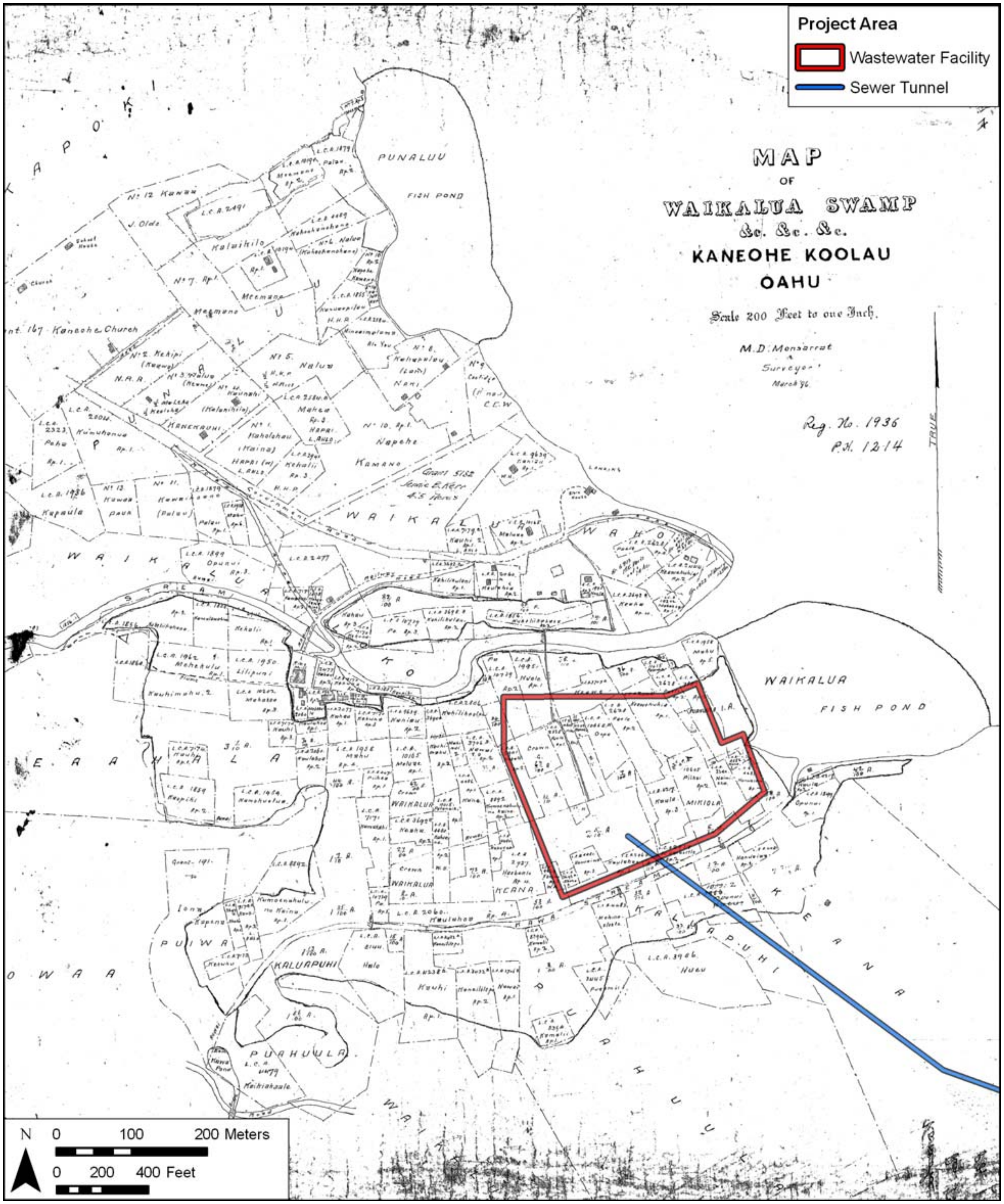

Figure 12. 1896 map of Waikalua Swamp (RM 1936), M.D. Monsarrat, surveyor, showing LCAs within and adjacent to Kāne'ohe WWPTF; Kāne'ohe Stream is to the north and Kawa Stream is adjacent to Kāne'ohe WWPTF's southern boundary

Mid 1800s to early 1900s

The mid-19th century brought great changes to Kāneʻohe Ahupuaʻa, including private and public land ownership laws during the Māhele, commercial rice and sugar cultivation, and ranching. Agricultural cultivation and ranching established the region as a source of market resources for Honolulu and beyond. Fishponds also became commercial entities during this period.

3.2.3.1 Sugar

One of the earliest sugar plantations on Oʻahu was owned by Charles Coffin Harris, who came to Hawaiʻi in 1850, planning to practice law. He established the Kāneʻohe Sugar Plantation Company (circa 1865) on 7,000 acres of Queen Kalama's land (Dorrance and Morgan 2000:41). In 1871, Harris bought Queen Kalama's Koʻolaupoko properties from her heir, Charles Kanaina, as well as some land in Honolulu for $22,448. The sale included "…livestock, tools, fishponds, and fishing rights" (*Bureau of Conveyances Records* Book 34:53, in Devaney et al. 1982:29); the fishponds of Waikalua Loko and Keana, adjacent to Kāneʻohe WWPTF were part of this sale. C. C. Harris's plantation closed in 1891 since the sugar yield was not enough to support the operation (Dorrance and Morgan 2000:41). Harris's daughter and heir, Mrs. David Rice, incorporated the lands as Kaneohe Ranch and converted them to stock farming. James B. Castle purchased a large block of their land holdings in 1907 (Montgomery 1971, cited in Dorrance and Morgan 2000:42).

3.2.3.2 Rice

Rice cultivation was to eventually supersede taro and dominate the lowlands of Kāneʻohe. The ancient taro *loʻi* and *ʻauwai* irrigation systems were used and additional new ditches were built to support rice cultivation. During the height of rice cultivation (circa 1880-1920), Chinese dominated the business. "To a great extent the rice business, growing and milling was controlled by Chinese *hui* (firms), which recruited laborers from China, handled investment capital from rich absentee landlords, and tallied profits" (Devaney et al. 1982:49). By the late 1880s, virtually the entire floodplain areas of Kāneʻohe were under rice cultivation. In 1892-1893, the Kaneohe Rice Mill was erected and began production on property adjoining Waikalua Stream, *mauka* of the Kāneʻohe WWPTF portion of the project area. A flume brought water from the river to the rice mill. About twice a week a steamer came into Kāneʻohe Bay to pick up and transport rice to market in Honolulu (Ching, personal communication, in Allen et al. 1987:295).

By the 1920s, rice had gradually declined in importance due to a number of factors. Two of the primary reasons for this decline were the beginning of rice production in California and the "annexation of Hawaii by the United States in 1898 [which] resulted in restrictions on the number of Chinese laborers arriving from the Far East" (Devaney et al. 1982:53). However, rice as well as some taro cultivation, continued up to circa 1960.

3.2.3.3 Pineapple

The commercial cultivation of pineapple in Kāneʻohe began in the 1890s and the first decade of the 20th century. From approximately 1910 to 1925, pineapple cultivation was a major industry in this area. In 1911, the company of Libby, McNeill and Libby built a pineapple cannery in He‘eia. At its peak, 2,500 acres were under pineapple cultivation on Windward O‘ahu (Harper 1972) stretching from Kāne‘ohe to Kahalu‘u. Most of the pineapple lands in Kāne‘ohe were "located below the Pali where the golf course, Hawaii Loa College, and the Hawaiian Memorial Park are today" (Kelly 1987:295-296). A *heiau*, Kaualauki Heiau in He‘eia, was mostly destroyed by pineapple field clearance during this time – a likely fate of many archaeological sites (Kelly 1987:295-296). In 1919, the Kaneohe Ranch Company and Heeia Agricultural Co., Ltd. leased 1000 acres of land in He‘eia, Kāne‘ohe, and Kailua, formerly planted in sugar, to the Libby Company for a term of 17 years. In 1917, Libby leased an additional 600 acres in He’eia (Libby, McNeill and Libby Ms:2, cited in Kawachi 1990). While the rice fields that covered old taro lands were mainly located near streams and near the coast, the pineapple fields were also grown on the slopes of higher lands, usually on land subleased to individual Japanese farmers:

> Pineapples were planted by individual Chinese and Japanese farmers on moderately sloped hill land where rice and taro could not be grown…these areas included the dissected alluvial terraces and the lower slopes and spurs of the Ko‘olau range. (Miyagi 1963:115)

The change to the Windward landscape due to pineapple cultivation is illustrated by the following passage from a 1914 magazine article:

> At last we reached the foot of the Pali…Joe and I looked over the surrounding hills, but looked in vain for the great areas of guava through which but a few months ago we had fought and cut our way. As far as the eye could reach pineapple had taken the place of the forest of wild guava. The newest industry in Hawaii was beginning even to press upon the cane fields of this side of the island. (Alexander 1914:318, cited in Devaney et al. 1982:62)

The pineapple fields were abandoned when Molokai and Lāna‘i pineapple cultivation began to boom, and Libby dissolved the Ko‘olaupoko enterprise (Kelly 1976:47). The cannery closed in 1923 (Dorrance 1998:95), and most of the former pineapple land went to grass, some of which was used to graze cattle. Several of the small farmers returned to rice cultivation at that time (Kelly 1975:47).

3.2.3.4 Ranching

English Captain George Vancouver introduced cattle and sheep to O‘ahu in 1793 (Henke 1929:8), and by the 1840s, cattle had multiplied into a large herd (Devaney et al. 1982:70). At its peak, Kaneohe Ranch extended from the ocean in Kailua to the Pali and included 12,000 acres and 2,000 head of cattle (Henke 1929:62). By the mid-1860s, the cattle were so numerous as to cause environmental degradation. Alien grasses and other species, such as pigeon peas, were introduced to the area as cattle fodder (Henke 1929:62). Much of the land modification in the upland and hilly portions of Kāne‘ohe may be the result of heavy cattle grazing over a long period of time.

> A view from the Pali looking toward Kaneohe in 1854 revealed that there were "hundreds of cattle…feeding on the rich pasture with which these plains were covered" (Bates 1854:104). By the mid-1860s, we have an indication that livestock was altering the landscape. The undulating plains at the foot of Nuuanu

> Pali (Kekele lands) were described as “a rich land a while ago but now there are not many plants because animal are permitted there.” (Sterling and Summers Ms.:207 in Devaney et al. 1982:70)

Cattle and horse grazing in Kāne‘ohe, including Mōkapu Peninsula, continued into the 1900s (Fiddler 1956:1). “In those days [early 1900s] Mōkapu was a grazing ground for resting the horses. Twice a year a leader rides a horse and drives the horses from around the Bay out to Mōkapu” (Interview with Mrs. Polly Ching by Marion Kelly 1976, in Devaney et al. 1982: 72).

3.2.3.5 Fishponds

As previously mentioned, during the Māhele, fishponds were considered to be part of the land to which they were attached. As such, the fishponds were typically designated as Crown or Government Lands, or awarded to the *ali‘i* as Konohiki Lands. Some of the lands owned by the government and *ali‘i*, along with the fishponds, were subsequently sold to entities with commercial agricultural pursuits, such as sugar cane and pineapple cultivation, or ranching:

> Once fishponds were declared private property, they were taxed by the government along with the rest of the real property. When commercial agriculture brought promises of high profits, few large landowners paid much attention to the fishponds attached to their land holdings. They were satisfied to lease them to Hawaiians or Chinese who had the technical knowledge necessary to properly manage fishponds. Yet, when disaster struck, such as a break in the fishpond wall, few lessees could afford the capital required to undertake repairs. As a result, many fishponds deteriorated with the passage of time, and the practice of aquaculture among the people, for all practical purposes, ceased. (Devaney et al. 1982:143)

By 1901 only 16 fishponds were present within Kāne‘ohe Bay, perhaps less than half of the fishponds that were present in the mid-1800s. Figure 13 shows Waikalua Loko Fishpond, and the vicinity of the Kāne‘ohe WWPTF in the early 1900s. By 1910, the area was under intensive rice cultivation (Figure 14). Nu‘upia Fishpond was a very large fishpond at the time, as shown on the 1919 War Department Fire Control Map (Figure 15).

3.2.4 Early 1900s to Present

In 1917, two College of Hawaii professors visited Mōkapu Peninsula. They noted the lack of boundaries between land divisions and the “treeless pasture marked by cattle trails, with grazing herds of horses, mules, and cattle.” At the time, the area was considered to be a “remote and little-known region of Oahu. At Nuupia Pond they saw the “hovel” of a Chinese keeper. In 1917 the fishponds were largely operated by Asians” (Bowen 1974:131-132).

In 1918, a military reservation was built on the Mōkapu Peninsula at Kāne‘ohe Bay; Fort Hase was commissioned and was known as the Kuwaahoe Military Reservation or Camp Ulupau. Now known as the Marine Corps Base Hawaii (MCBH), the base helped lead to a boom in commercial and residential development in and around Kāne‘ohe.

A 1919 War Department map (Figure 15) shows an unpaved road extending along, and in some cases in, Kāne‘ohe Bay between Waikalua Loko Fishpond, and Nu‘upia Fishpond. Travel

Figure 13. Waikalua Loko Fishpond, in the early 1900s (from *Honolulu Star-Bulletin* June 23, 2000)

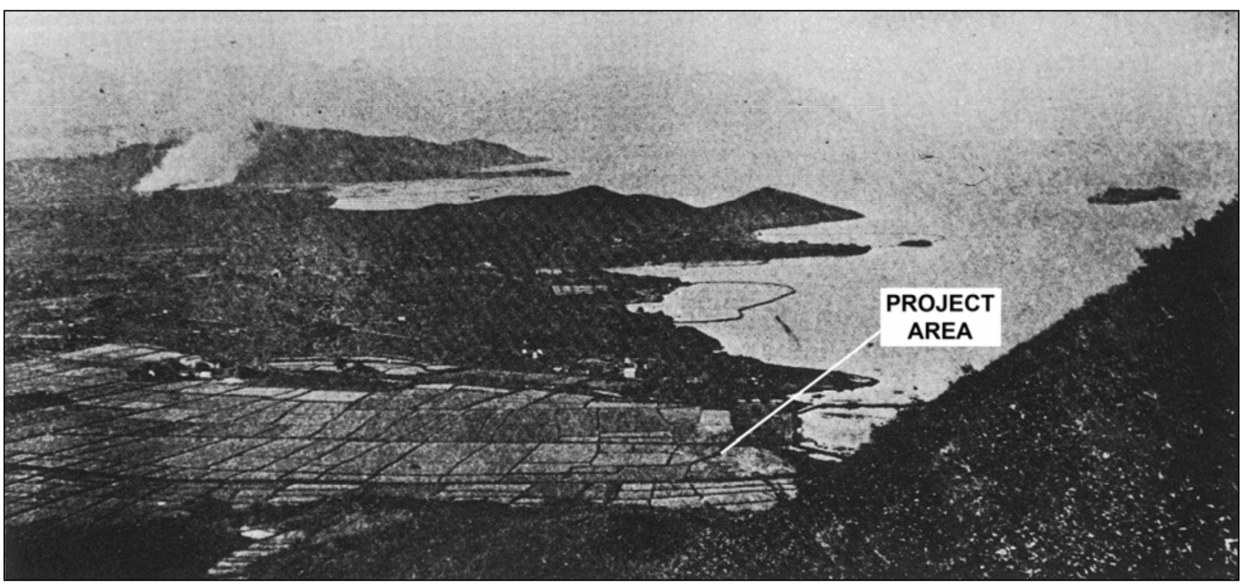

Figure 14. Rice fields in the “Waikalua Swamp” area circa 1910 (*Mid-Pacific Magazine* Sept. 1913, in Devaney et al. 1982:53), showing the location of the Kāne‘ohe WWPTF portion of project area

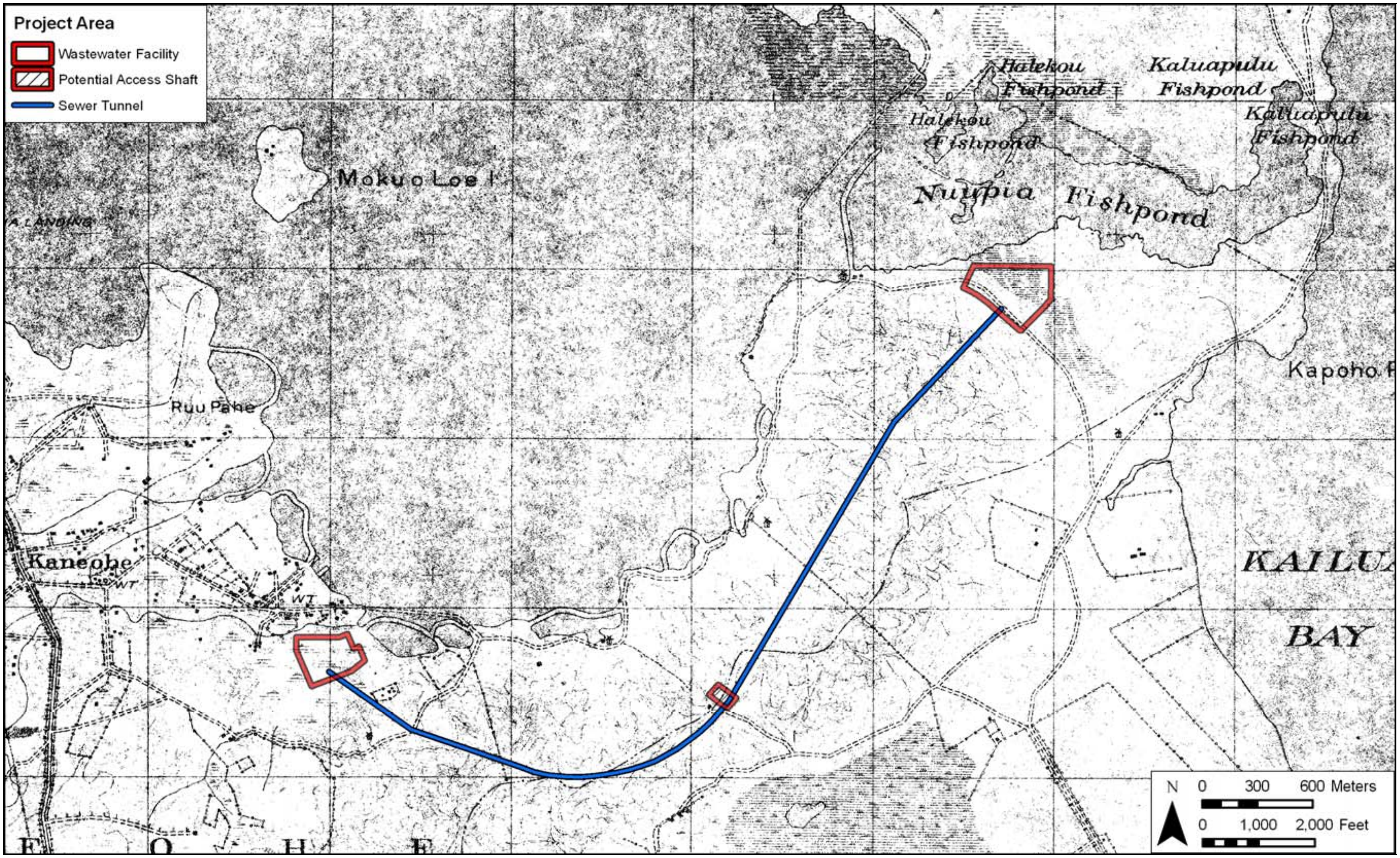

Figure 15. 1919 U.S. War Department Fire Control Map, Kaneohe and Waimanalo quadrangles, showing the project area and features discussed in the text

by boat or traveling on foot from the project area vicinity was the usual means of transportation until cars were commonly owned (Fanning 2008:88-89).

The extensive grazing and agricultural uses of the inland areas of Kāneʻohe increased erosion and infilling of near shore marine environments, including fishponds. Waikalua Loko's walls were reconstructed in 1930, although the fishpond retained its original configuration. Three mortared *mākāhā* (gates) were also added at that time (Devaney et al. 1982:146-147). In the 1960s Mr. Koyama, the fishpond operator, was harvesting 100 pounds of mullet each month (Dashiell 1995:9). In addition to being a bountiful source of fish, in 1976 oysters were being cultivated in Waikalua Loko (Devaney et al. 1976:145).

Devaney et al (1982:147) note that Nuʻupia Fishpond was modified in the 1940s and "recently" (1982). The pond measured 215 acres (Cobb 1902) in 1901 and by 1982 consisted of 180 acres. Local Japanese (Little-neck) clams (*V. philipinarum*) were introduced into various ponds along Kāneʻohe Bay between 1920 and 1939, and Nuʻupia Fishpond was well-known as a desirable clamming destination during the September to October season. However, in 1969 soil erosion caused a "massive wipe-out of the transplanted Japanese little-neck clams" (*Honolulu Star-Bulletin* June 13, 1969 in Devaney et al. 1982:101).

In the post-World War II years, the dairy industry rose to prominence over beef cattle ranching. The shortage of available land due to urban expansion, the shortage of fee simple land, and the high price of land leases forced farmers in the dairy districts near Honolulu (e.g., Koko Head) to relocate to more remote areas of Oʻahu (Durand Jr. 1959:241). In the 1950s, Kailua-Kāneʻohe was an important dairy district of Windward Oʻahu. Dairy farming was dominated by Caucasians particularly of Portuguese and Spanish ancestry, and secondarily Japanese, farmers (Durand Jr. 1959:235). "Among the names of island dairymen, illustrating the Portuguese-Spanish-Mainland importance…are…Brazil, Carlos, Campos, Costa, Ferreria, Foster, Freitas, Knowles, Medeiros, Moniz, Ornellas, Rapoza, Santos, Toledo, Vause and White" (Durand Jr. 1959:235). This period, however, was relatively short-lived as the opening of the Pali route, exorbitant land prices in Honolulu, and more automobiles on Oʻahu contributed to rapid urbanization in Kailua-Kāneʻohe (Durand Jr. 1959:244-245). Many landowners decided to develop their land for suburban housing and terminated leases with farm leaseholders.

By the end of World War II, ranching was no longer economically viable for Kaneohe Ranch, so the ranch became primarily a landlord to other farmers. Following the war, residential developments began to changed the face of Kāneʻohe Ahupuaʻa. The opening of the Wilson Tunnel and the expansion of the Pali Highway in the 1950s and 1960s — creating an easier passage from Honolulu through the Koʻolau Mountains to windward communities — lead the way to a development boom on the windward side of Oʻahu. High tax rates on real estate sales forced many old-time landowners to lease their land to residential developers rather than sell on a fee-simple basis. Kaneohe Ranch at one time leased their land to over 5,000 single-family residential lots in Kailua and Kāneʻohe. The vast majority of the leaseholds were later sold to the lessees.

3.2.5 Recent Project Area Development

Figure 16 through Figure 19 are historic maps of the project area and vicinity showing a general lack of development in the area until after the early 1950s. Urbanization and associated

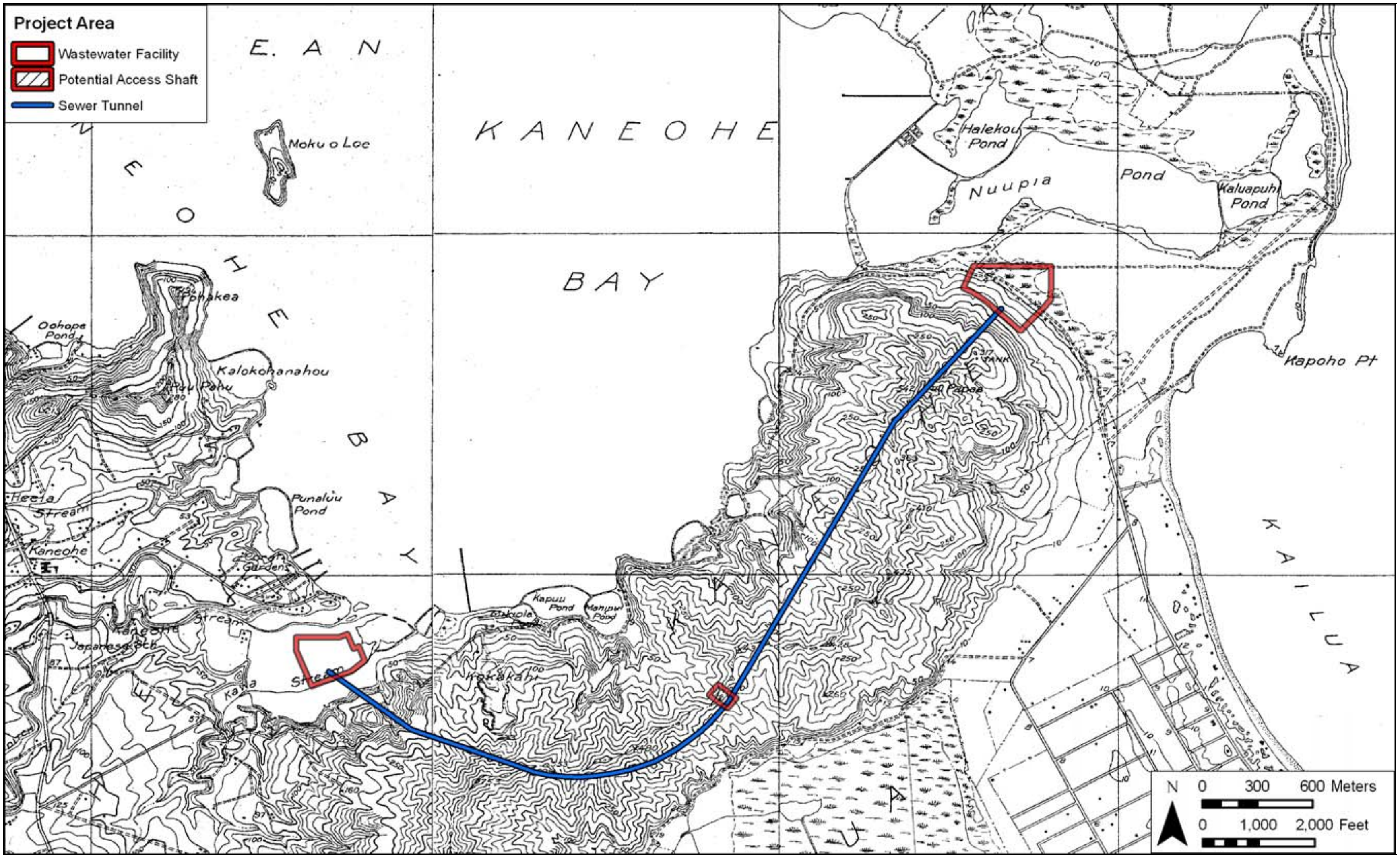

Figure 16. Portion of 1928 U.S. Geological Survey 1:20,000 Scale Topographic Map, Kaneohe and Mokapu quadrangles, showing the approximate locations of the project area and planned sewer reconstruction work, and features discussed in the text

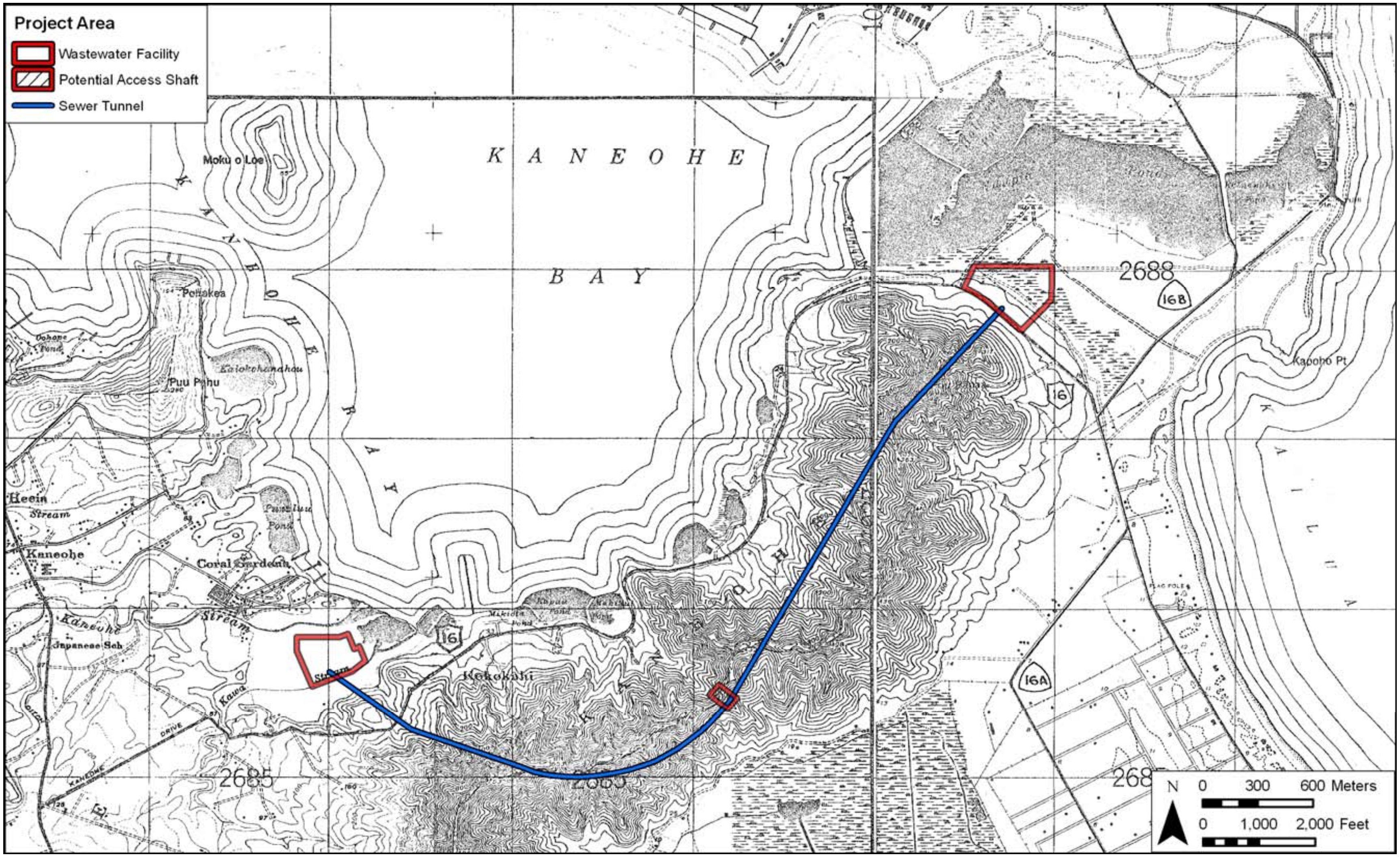

Figure 17. 1943 War Department 1:20,000 Scale Terrain Map, Kailua and Kaneohe quadrangles showing the project area and vicinity

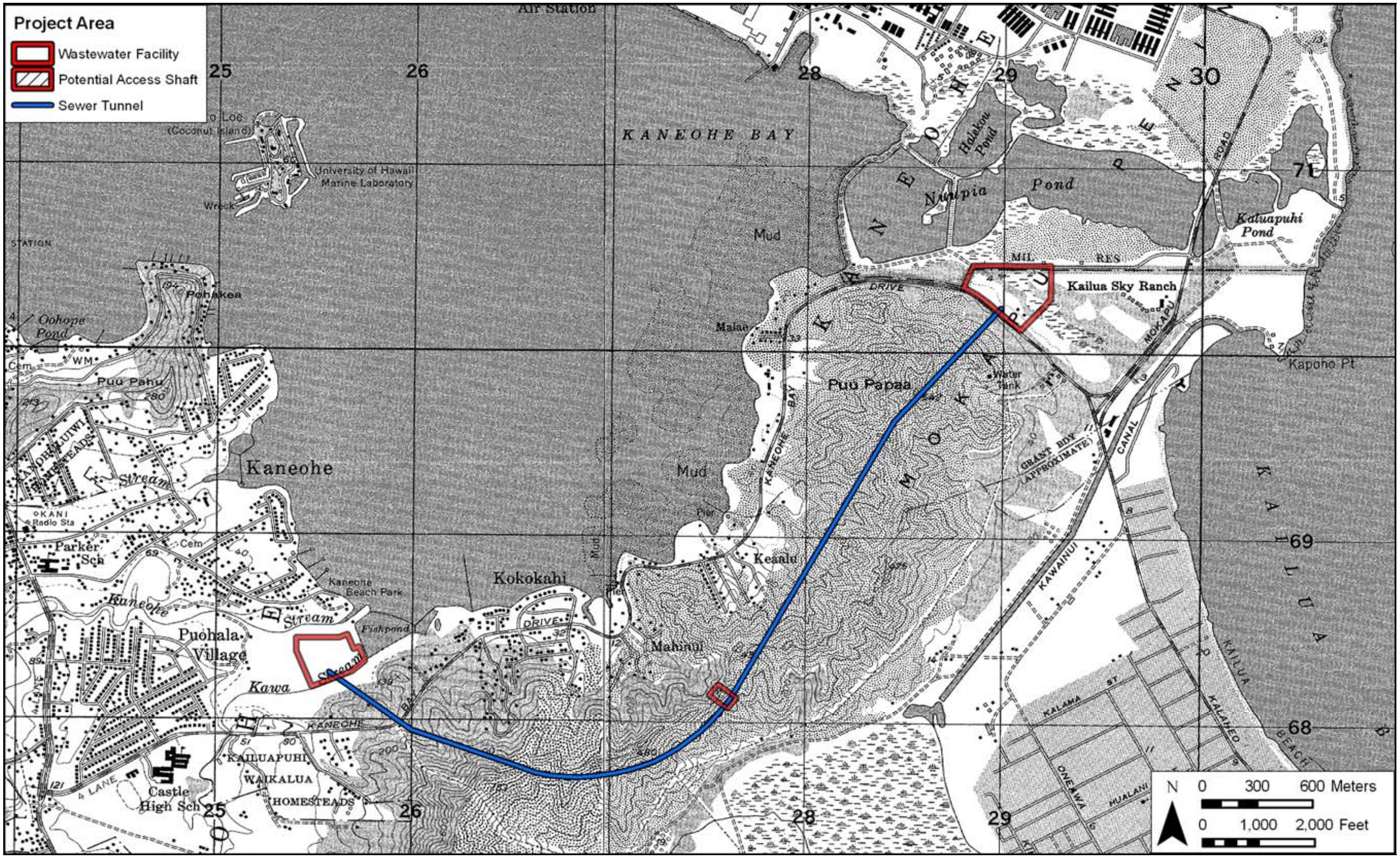

Figure 18. Portions of 1954-1955 Army Map Service 1:25,000 Scale Topographic Maps, Mokapu and Kaneohe quadrangles, showing the project area and vicinity

Figure 19. 1978 U.S. Geological Survey Orthophoto, Kaneohe and Mokapu quadrangles, showing the project area and vicinity

improvements such as flood control, road construction, and construction of the Kāneʻohe sewer plant, extensively modified the Kāneʻohe WWPTF portion of the project area during this period. The Kāneʻohe Sewage Treatment Plant was constructed in 1963. Bay View Golf Course, adjacent to Kāneʻohe WWPTF was originally built in 1963 as a 9-hole course.

Kawa Stream, which formerly flowed into Waikalua Loko fishpond, was channelized in the 1960s and 1970s to flow into Kāneʻohe Bay. Kāneʻohe Stream, which had provided water for *loʻi* and later rice, was also channelized and dammed in the 1970s (Dashiell 1995:9).

Multiple upgrades have been made within the Kāneʻohe WWPTF. In 1978, the plant was converted to a wastewater pump station; in 1994 it was converted to a preliminary treatment facility; and in 1998, upgrades were implemented. The adjacent Bay View Golf Course was redesigned and rebuilt in the late 1990s to include an 18-hole course, a miniature golf course, a driving range, and lighting for night play.

The Kailua Wastewater Treatment Plant was originally constructed in 1965 for Kailua town and its surrounding communities. In 1994, Kailua WWTP was expanded after Ahuimanu and Kāneʻohe treatment plants were converted "to preliminary treatment facilities" (City and County of Honolulu 2009). Nearby ʻAikahi School and ʻAikahi Shopping Center were built between 1960 and 1970.

Nuʻupia Fishpond is generally shown as one large fishpond on historic maps (see also Figure 9 and Figure 15). However, a 1954-1955 Army Map Service topographic map (see Figure 18) and a 1978 aerial photograph (see Figure 19) show Nuʻupia Fishpond divided into several separate fishponds. The Nuʻupia Fishpond Complex, designated as SIHP # 50-80-11-1002, consists of eight fishponds that extend from Kāneʻohe Bay east to Kailua Bay and include Halekou, Paʻakai, Kaluapuhi, Nuʻupia ʻEkani, Nuʻupia ʻElua, and ʻNuʻupia Ekolu. A "U.S. Fish and Wildlife Service map of the Nuʻupia Ponds" circa 1984 shows the locations of the eight fishponds and their proximity to the "County Waste Water Treatment Facility", the current Kailua WWTP (Figure 20). Note that "Shrub Forest" is to the north and west of Kailua WWTP.

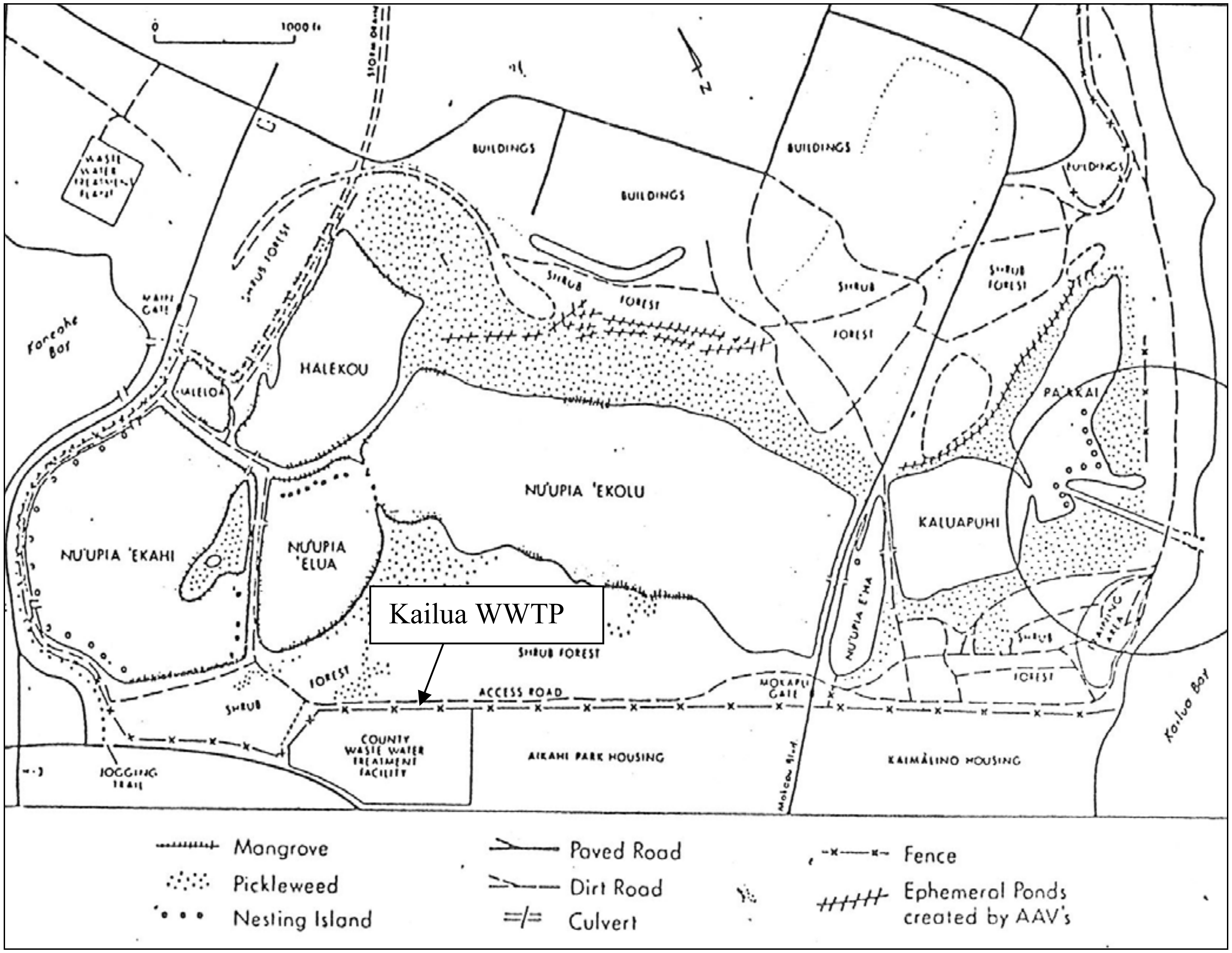

Figure 20. “U.S. Fish and Wildlife Service map of the Nu‘upia Ponds” circa 1984 showing the locations of the eight Nu‘upia Fishponds within SIHP -1002 and their proximity to the “County Waste Water Treatment Facility”, the current Kailua WWTP (adapted from Cordy 1984:3)

3.3 Previous Archaeological Research

An overview of archaeological studies conducted in the vicinity of the current project area is summarized in Table 2 and indicated on Figure 21. A discussion of these archaeological findings relevant to each portion of the project area follows. Note that no previous studies have been conducted within the vicinity of the proposed intermediate tunnel access shaft although extensive excavations were conducted nearby during the construction of Interstate H-3.

Following the previous archaeological research discussion, burials previously found within the vicinity of the project area are shown on Figure 22 and Table 4 provides data related to burials found within the vicinity of the project area, as well as their distance from the current project.

Table 2. Previous Archaeological Studies in the Vicinity of the Study Area

Reference	Type of Investigation	Location	Findings
McAllister 1933	Island-wide survey	Island wide	Identified 4 historic properties in the vicinity of the study area: SIHP -359 (Pahukini Heiau), SIHP -360 (Holomakani Heiau), SIHP -364 (Nuʻupia Fishpond Complex), and SIHP -370 (Kawai Nui Marsh)
Davis et al. 1976	Archaeological Investigations	Kailua Effluent Force main; Ulupaʻu Dunes	Site 50-Oa-G5-67; subsurface cultural deposit containing 89 pre-contact traditional Hawaiian burials, fire pits, artifacts, and midden.
Hammatt et al. 1985	Archaeological Coring and Testing	Nuʻupia and Halekou ponds	Cross-section of fishpond wall dividing Nuʻupia and Halekou ponds yielded information on wall construction. Wall was constructed of coral boulders and cobbles procured from nearby reef exposures. Test excavations just north of the ponds yielded diverse shell midden and basalt debitage associated with stone tool manufacture. Archaeological monitoring was recommended for any future ground disturbance in the vicinity.

Reference	Type of Investigation	Location	Findings
Clark and Riford 1986	Archaeological Salvage Excavations	Nani Pua Gardens II Subdivision (TMK 4-5-30:43)	Salvage excavations at Bishop Museum site 50-Oa-G5-101 (SIHP # -2937). Two human burials and additional fragmentary remains were found. Reports ^{14}C date of A.D. 1070-1405; substantial discussion of lithic finds
Hammatt 1989	Subsurface Reconnaissance	44-291A Kāneʻohe Bay Drive (TMK: [1] 4-4-007: 8, 10)	Subsurface testing documented the presence of imported fill sediments and naturally deposited marine clays atop limestone bedrock. No historic properties identified. No further archaeological work was recommended.
Tuggle and Hommon 1986	Historic Property Inventory	Kaneohe Marine Corps Air Station	Survey undertaken to determine whether previously identified historic properties were extant. Historic properties previously identified and relocated include: Mokapu Burials (SIHP # -1017), ruins (SIHP # -2885) and spring (SIHP # -368) near Puʻuhwaiʻiloa, fishponds and salt works (SIHP # -1002); ruins in Heʻeia (SIHP # -2883)
Stride et al. 1994	Inventory Survey and Subsurface Testing	Waikalua Road (TMK 4-5-05: 1,2, 12-14) 3.3 acres at shoreline	No significant finds in eight backhoe trenches
Jackson et al. 1993	Archaeological Monitoring, Reconnaissance, and Test Excavations	Nuʻupia Pond	6 historic properties identified on the south side of Nuʻupia pond, including: 2 boulder alignments (SIHP -4641 & -4643), two cobble pavements (SIHP -4638 & -4639), and two lithic scatters (SIHP -4640 & -4642). Of note is SIHP -4638, a limestone cobble pavement that was interpreted as a possible burial.

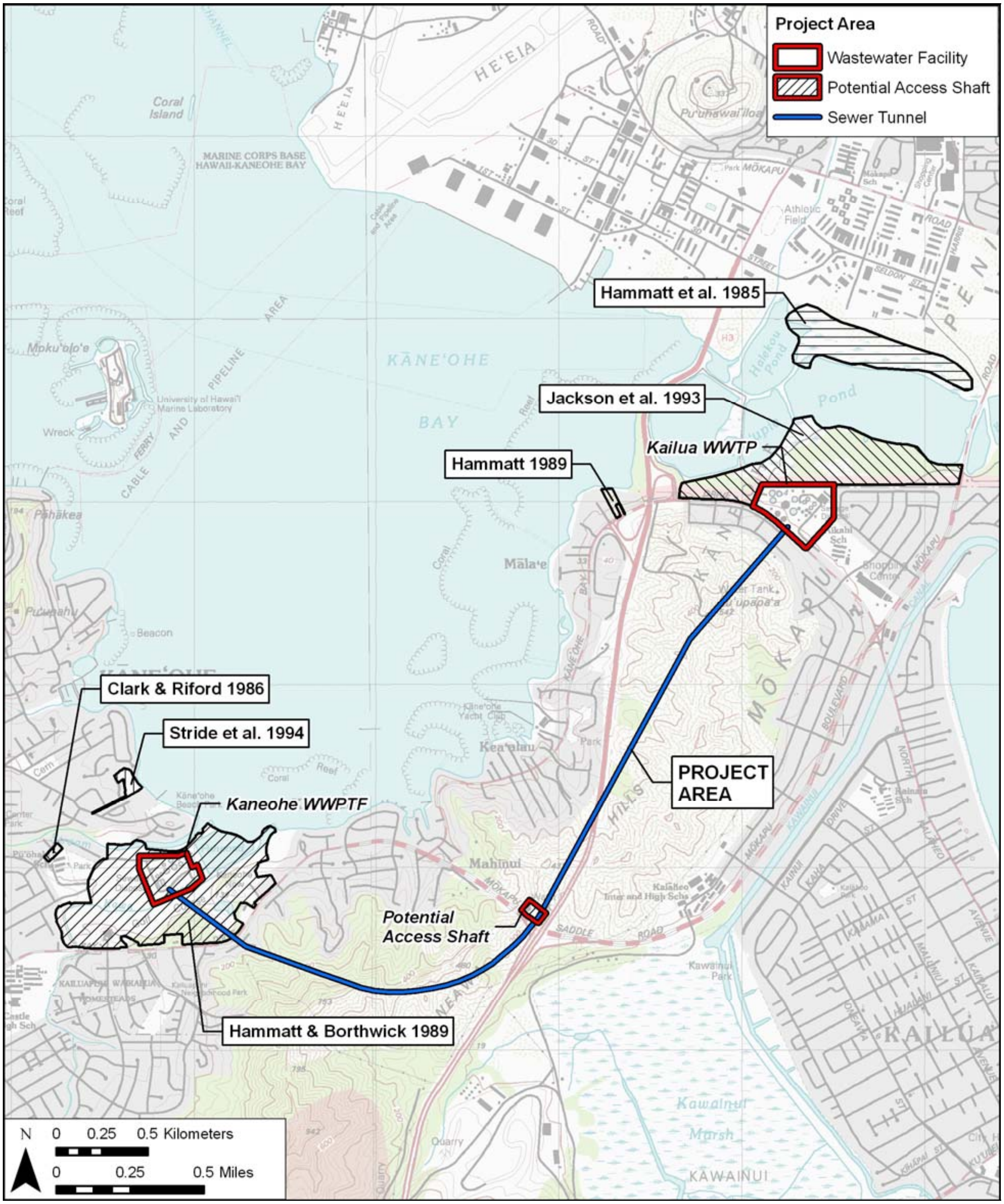

Figure 21. Previous archaeological studies conducted within the vicinity of the project area.

3.3.1 Early Archaeological Surveys

3.3.1.1 Thrum 1915

Thrum reported in 1915 on the state of several *heiau* in Kāneʻohe: Maunahuia within Wakaluawaho that was "in ruins" at the foot of the *pali*; Kukuiokane at Luluku, formerly a large platform; Kaluaolomana at Puuwaniania, a medium walled structure that was still present, and Kawaʻewaʻe, also present. Three other Kāneʻohe *heiau* that were associated with each other existed at one time, although that was the extent of Thrum's knowledge. They were: Pule at Keaahala, Kuakala, nearby, and Naonealaa at Waikalua, "said to have been the principal of the three" (Thrum 1915:90) and situated at the beach end of Waikalua Drive, near Kāneʻohe WWPTF.

Thrum also identified an un-named *heiau* on Mokapu, describing it as, "A large heiau of husbandry class; Hina and Ku its deities" (Thrum 1906:48). No other location was provided.

3.3.1.2 McAllister (1933)

The first systematic archaeological study of the Kāneʻohe area was conducted by J. Gilbert McAllister of the Bernice P. Bishop Museum in the 1930s. McAllister (1933) consulted with knowledgeable informants about both physical and legendary sites of each district during his island-wide survey of Oʻahu in the 1930s. The following are brief descriptions of sites near the Kāneʻohe WWPTF project area. A description of the McAllister site within the vicinity of Kailua WWTP follows.

> Site 347. Kalaoa heiau, Waikalua, Kaneohe. This heiau was located on an elevation to the left of the road [Waikalua Road] leading to the Kaneohe municipal camping grounds just beyond the lane which leads to the Coral Gardens. Nothing remains of the heiau, the stones having been used in the construction of the [Kaneohe Rice] mill. The heiau was built by Laamaikahiki, according to John Bell, who took me to the site. (McAllister 1933:178)
>
> Site 348. Site of the houses of Laamaikahiki, Waikalua, Kaneohe. The home of David Trask now occupies the site….The sand in front of the place are known as Naonealaa and were tapu to the commoner when the alii lived there.
>
> On this same elevation Laamaikahiki wanted to build this heiau, Kalaoa (Site 347), but he was advised by his kahuna to place it considerably farther from the chief's houses, for the women of the household would be too close to the sacred inclosure tapu to them.
>
> Naonealaa is listed by Thrum as a heiau. (McAllister 1933:178)
>
> Site 349. Waikalua Fishpond, adjacent to Waikalua, Kaneohe. The rebuilding of the pond has been completed. The wall was 1420 feet long of waterworn basalt 3 to 4 feet high but somewhat wider. The pond covers 11 acres. (McAllister 1933:178)
>
> Site 350. Two ponds, Kailua side of Waikalua. The pond in use is said to be Keana with an area of 3.5 acres. According to Bell, the name of the other is

Kalokohanahou. Its wall is broken. Both were built of waterworn basalt. The dirt-filled wall of Keana is wide enough for trees to grow on it. (McAllister 1933:178-179)

Site 351. Three adjacent ponds, located off the lands of Mikiola and Mahinui in Kaneohe. The two end ponds were probably built first, the middle pond being added later so as to take advantage of the walls of the other two. The pond on the east is known as Mahinui and that on the west as Mikiola. The name of the middle pond is Kaluoa, according to John Bell, but appears as Kapuu on a map in the Bishop Estate office. The wall of Mikiola is broken. (McAllister 1933:179)

Site 352. Ahukini heiau, Keana, Kaneohe. A small structure, 70 by 127 feet, built on the top of an elevation 1200 feet from the sea…The only features remaining are the low walls, unusual because they are built of stones a few inches in size…most of the remains are scattered, for it is very easy for the cattle to disturb the small stones…When the drums at this heiau were beaten they could be heard over Kaneohe, but not just on the other side of the low ridge in Kailua. (McAllister 1933:179)

Site 353. A spring on the land known as Keana (now Kokokahi), called Kinikailua-Manokaneohe, as it is said that the people from both Kailua and Kaneohe died in great numbers from drinking its waters. (McAllister 1933:179)

Site 354. Kawaewae Heiau, Kanieohe side of the ridge which divides the district and Kailua.

This is one of the five heiaus said by John Bell to have been erected by Olopana. Ahukini, Pahukini, Holomakani, and Puumakani are the other four. It is on top of a small knoll and consists of one large enclosure 120 by 253 feet with a small terrace on the north side which follows the contours of the land. As the structure was used as a cattle pen for many years any traces of heiau features have been obliterated, and it is not known where the opening to the heiau was situated. The walls are massive, averaging about 5 feet in width and from 4 to 7 feet in height according to the contours of the land. The inside corners of the wall are rounded; the outside corners appear more angular. (McAllister 1933:179)

McAllister's (1933:184) Site 364 is within close proximity to the Kailua WWTP project area:

Site 364. Halekou, Kaluapuhi, and Nuupia, three adjoining fishponds on the Mokapu Peninsula. Kaluapuhi on the east covers 24 acres and is connected with Kailua Bay by one outlet (*makaha*), by means of which it can be flooded at high tide. It is separate from Nuupia by a wall. Halekou of 92 acres, and Nuupia, of 215 acres, are on the west, separated from Kaneohe Bay by a long wall.

Solomon Mahoe tells me that there was formerly another pond here called Muliwaiolena. Fornander [1880:262] mentions this as the name of a little brook near which the commander of the Oahu troops was shot by Kaeo's foreign gunner when Kaeo was not allowed to land in Koolaupoko.

MacCaughey (58) writes:

> We walked along the wall that separated the pond [Nuupia] from the bay. This wall, like those of other fishponds, is four to six feet wide about eighteen inches above the water; its average total height is some five feet. It is made up of two laid stone walls. The central part between the walls is filled with earth and loose rubble. The path lies along the middle of the wall, and owing to inequalities in the settling and packing of the rubble, it is very irregular, with abrupt pits and knolls. (McAllister 1933:184)

Although McAllister identified other sites on Mokapu Peninsula, they are in Heʻeia Ahupuaʻa, north of the current project area.

3.3.2 Studies Conducted within the Vicinity of Kāneʻohe WWPTF

Three archaeological studies have been conducted within close proximity of the Kāneʻohe WWPTF. A preservation plan was also prepared for the Waikalua Loko fishpond (Dashiell 1995), which is adjacent to the east portion of the Kāneʻohe WWPTF.

3.3.2.1 Proposed Nani Pua Gardens II Subdivision Project

In 1986, the Bishop Museum conducted archaeological salvage excavations of site G5-101 (SIHP # -2937) within TMK 4-5-030:043 (Clark and Riford 1986), approximately 160 meters northwest of the project area's western boundary. This pre-contact Hawaiian habitation site is within the Nani Pua Gardens II Subdivision and was identified during archaeological investigations. The 1.7 acre parcel is bordered on the north and east by Kāneʻohe Stream.

Preliminary investigations revealed a surface layer with lithic artifacts and a buried cultural layer. Additional sites recorded in the area included two lithic scatters (Site 50-Oa-G5-100), a former rice field and taro terrace (Site 50-Oa-G5-104), an Italian prisoner-of-war camp, and the Kaneohe Rice Mill. Subsurface testing recovered a relatively early radiocarbon date of A.D. 1070-1405. A vast assemblage of lithic artifacts suggested the historic property was primarily used by "craftsman specializing in the manufacture of stone tools, primarily adzes" (Clark and Riford 1986:110). Two human burials were encountered that were in a fully extended position, and lacked cultural material. Additional fragmentary remains were encountered in the context of pre-contact basalt artifacts (Clark and Riford 1986:45, 104). Clark and Riford (1986:110) concluded the historic property housed craftsmen specializing in the production of stone tools, primarily adzes.

3.3.2.2 Waikalua Road, Kāneʻohe Bay Project

In 1993, CSH conducted an archaeological inventory survey within 3.2 acres along the shoreline of Kāneʻohe Bay at Waikalua Road, approximately 160 meters north of the current Kāneʻohe WWPTF project area (Stride et al. 1993). Research indicated a high probability that the project area had been a traditional Hawaiian settlement. The property was also the Coral Gardens, a 1915 to 1940 resort hotel. Eight backhoe trenches were excavated to determine the presence or absence of cultural deposits. No cultural material or human remains were observed during the survey or backhoe testing other than modern trash. No further archaeological work was recommended for the project.

3.3.2.3 Bay View Golf Course Archaeological Survey and Assessment

In 1989, CSH conducted an archaeological survey and assessment of the 90-acre Bay View Golf Course for a proposed expansion (Hammatt and Borthwick 1989). Bay View Golf Course is adjacent to the west and south portions of the Kāne‘ohe WWPTF. Background research indicated over 40 Land Court Awards granted for this area that was traditionally used for taro planting and aquaculture within the three fishponds along Kāne‘ohe Bay. Modern development of the area including the golf course, sewage treatment plant (Kāne‘ohe WWPTF), surrounding residential subdivisions and flood control projects, had caused extensive modifications of the land.

Waikalua Loko fishpond and Waikalua fishpond were the only two archaeological features found within the project area. Waikalua Loko fishpond has been a continuously functioning fishpond since pre-contact; and Waikalua fishpond was in poor condition due to mangrove intrusion, but still showed an intact seawall. Both fishponds were recommended for preservation, and archaeological monitoring during initial clearing and grading was recommended.

Subsurface testing was conducted between Kāne‘ohe and Kawa Streams in a strip of undeveloped pasture between Kāne‘ohe WWPTF and the Bay View Golf Course, in City and County land. The area was thought to be the only possibly undisturbed portion of the floodplain within the project area.

Eight trenches were excavated at 50-100 foot intervals with each trench averaging 7.5 meters long and averaging 230-240 cm. in depth (to water table). Both sides of the trenches were examined for cultural materials and features as well as changes in stratification. A soil profile description was made for each trench and samples of all subsurface deposits were collected. Elevation rise from Trench 1 to Trench 8 was approximately 3 feet.

The stratigraphic succession was uniform throughout all eight trenches with variation in depth and thickness of each stratum. A generalized soil profile description is presented below in Table 3.

Table 3. General Soil Profile Description for Proposed Bay View Golf Course Expansion (Hammatt and Borthwick 1989:34)

Strata	Depth (cmbs); (range in thickness)	Description
Stratum I	0-80 (60-120 cm)	Dark greyish brown silt loam to sandy clay contains basalt and coral gravel with modern trash, plastic, golf balls, bottle glass, abrupt wavy boundary. Modern mechanical fill
Stratum IIA	80-120 (20-60 cm)	Reddish brown, clay loam with fine strong angular blocky structure with clay and iron coatings between peds and pronounced iron stained root casts. Clear wavy boundary. Top 10 cm. typically has platy structure from compaction. A-1 horizon; natural deposit; buried agricultural soil

Strata	Depth (cmbs); (range in thickness)	Description
Stratum IIB	120-240+ (100-130+ cm.)	Grayish blue, clay, moderate medium angular, blocky with pronounced iron coatings on root casts. Gleyed soil with weak organic and iron staining. Bottom portion waterlogged. A-3 horizon; natural deposit; buried agricultural soil

Modern dumping of imported top soil mixed with construction fill, likely to reclaim the lowland areas for pasture land was evident throughout the project area. Former wetland taro/rice agricultural soil underlies this fill. Typically, these soils have partial gleying in the lower portions (due to poor drainage) and iron staining in the upper portion (from the water flow along crop roots). Strata IIA and IIB appear to have the same depositional origin (alluvium) with different weathering and variation in moisture regime and drainage. The A-1 horizon is better drained and has been more exposed to weathering. Samples were collected of Stratum IIA and IIB in most trenches, although these samples are estimated to be too low in organic content for dating.

Neither cultural materials nor features were observed within the backhoe trenches. The former *'auwai* shown on the early maps was not discerned in the profiles of any of the trenches, nor was there any indication of earthen field boundaries. Only "the original ponded, gleyed sediments associated with former taro/rice planting" was found beneath approximately 60-120 cm of fill (Hammatt and Borthwick 1989:40). No terracing or buried cultural material was observed. Archaeological monitoring was however recommended during initial grubbing and grading of the property.

3.3.2.4 Waikalua Loko Fishpond Preservation Plan

Dasheill (1995) prepared a preservation plan for the Waikalua Loko fishpond prior to the mid-1990s expansion of Bay View Golf Course. Two major components of the plan were proposed:

1. Preservation, restoration and maintenance of the pond based on its present [1995] construction features, environment and configuration. Actual operation of the pond could take place at any time, dependent on the desires of the owner and the WLFPS [Waikalua Loko Fishpond Preservation Society].
2. Interpretation program, which at a minimum may consist of a booklet and a self-guided tour along the public access route. Under the purview of the WLFPS, additional components of the interpretation program could be added, such as an interpretive center. The interpretive program was proposed to educate students or visitors to Hawai'i. The possibility that the Windward Community College may be interested in establishing some sort of effort was also proposed. (Dashiell 1995:10)

Founded in 1995, the Waikalua Loko Fishpond Preservation Society continues to manage and maintain, as well as conduct educational programs at the fishpond.

3.3.3 Studies Conducted within the Vicinity of Kailua WWTP

As previously mentioned, the Nuʻupia Fishpond Complex, designated as SIHP # 50-80-11-1002 is just north of the WWTP although shrub forest separates Kailua WWTP from the fishponds (see Figure 20).

3.3.3.1 Nuʻupia and Halekou ponds (Hammatt et al. 1985)

CSH conducted core sampling and test excavations that focused on the stratigraphy and surface features of the north end of Halekou and Nuʻupia ʻEkolu ponds (Hammatt et al. 1985), approximately 450 m north of the current project area. The majority of the eleven core samples extended to or below the base of the fishpond sediments. Basal sediments for all but one of the cores were coralline sand with coral gravel inclusions, indicating the area was open to the tides and ocean currents prior to the construction of the fishpond. The basal sediments of one of the eleven cores appeared anomalous in that it contained sandy loam composed entirely of volcanic sediments.

Findings during the testing include the wall dividing the Nuʻupia and Halekou fishponds, that was constructed of coral boulders and cobbles procured from nearby reef exposures. Additionally, test excavations just north of the ponds yielded diverse shell midden and basalt debitage associated with stone tool manufacture. Based on the extensive surface scatter, including some 237 lithic artifacts, and midden, it was postulated that a habitation and / or work site was once located on the Halekou and Nuʻupia ʻEkolu pond wall. Archaeological monitoring was recommended for any future ground disturbance in the project vicinity.

It should be noted that during the field work for the 1985 project, U.S. Marine Corps' amphibious assault vehicles traversed the marshy portions of the study area to improve the habitat of the Hawaiian stilts on an annual basis. The use of amphibious assault vehicles within Nuʻupia Pond continues today (Honolulu Advertiser 2003).

3.3.3.2 Nuʻupia ʻEkahi Fishpond Study (Jackson et al. 1993)

From 1992 to 1993 BioSystems Analysis Inc., conducted archaeological investigations at Nuʻupia ʻEkahi fishpond (Jackson et al. 1993) within an area that bounds the north and west portions of Kailua WWTP. The investigation consisted of monitoring vegetation clearance within the fishpond, and an approximately 120-acre archaeological survey. Subsurface excavations consisted of four backhoe trenches, five cores, and two hand dug test excavation units at SIHP 50-80-11-4640, a basalt tool and debitage scatter containing historic material that was identified during subsurface testing.

A total of six historic properties were found during the survey and include SIHP 50-80-11-4638 through -4643. SIHP -4641 is 100 m north of Kailua WWTP, -4638 is 150 m to the north, and the other four historic properties are between 200 to 350 m north.

SIHP -4638 is described as a limestone cobble "pavement" that may cover a burial. A circular hearth was found approximately 40 cm west of the pavement although "it appears to be relatively recent in origin and no midden or Native Hawaiian artifacts were observe in association with the feature." SIHP -4638 measured 3.75 m N/S by 2.5 m E/W (Jackson et al. 1993:18).

SIHP -4639 is described as a rectangular pavement or foundation consisting of 10-15 small angular and subangular limestone cobbles with well defined north and west sides, and irregular south and east sides. No midden or Native Hawaiian artifacts were observed. The historic property was previously disturbed by a communication wire that crosses the southern half of the pavement. SIHP -4639 measured 6.5 m N/S by 6.0 m E/W (Jackson et al. 1993:18, 21).

SIHP -4640 is described as a basalt tool and debitage scatter. Artifacts consisted of a basalt flake, a possible polished basalt flake, a basalt adze blank, a basalt adze pre-form and unmodified basalt debitage. A historic aqua colored glass bottle, clear glass fragments, a piece of lead shielding, lumber, and a piece of corrugated tin roofing were found within the historic property. SIHP -4640 measured 30 m E/W by 15 m N/S (Jackson et al. 1993:21).

Two 0.5 m-square test excavations were conducted within SIHP -4640 during which midden (100.6 g [grams] and 139.9 g) was recovered. Recovered midden consisted primarily of marine shellfish that “are typical of the littoral assemblage expected in environments near Nu‘upia pond.” Based on the “small amount of midden recovered from this site, it is apparent that significant amounts of food preparation was not occurring at this site” thus indicating the area contained “a small residential unit” used on a “temporary or periodic basis” (Jackson et al. 1993:78).

SIHP -4641 is described as a limestone boulder alignment. No midden, Native Hawaiian artifacts or historic disturbance were observed. SIHP -4641 measured 5.5 E/W by 2 m N/S (Jackson et al. 1993:21).

SIHP -4642 is described as a basalt tool and debitage scatter located near the former edge of the fishpond and in the vicinity of limestone outcrops. Artifacts within SIHP -4642 consisted of a basalt core, a utilized basalt flake, a notched basalt flake, a net sinker blank, and six unmodified pieces of basalt debitage. Historic disturbance includes an 8 cm diameter pipe extending from “the center of the eastern end for approximately 1 meter,” a standing post, some barbed wire, a metal framed structure with chain link fencing sides, and a modern glass and ceramic scatter. SIHP -4642 measured 15.8 E/W by 7.9 N/S (Jackson et al. 1993:21).

In the vicinity of SIHP -4642, an *‘ulu maika* pre-form, a piece of basalt debitage, an adze blank and an unmodified debitage basalt flake were also found. A low concrete curb measuring approximately 0.1 m high, 5.5 m E/W by 1.0 m N/S forms a “rectangular pen or enclosure open on the west side, abutting a limestone outcrop” (Jackson et al. 1993:21).

SIHP -4643 is described as a limestone boulder alignment located “5 m south of the limestone boulder edge” of the fishpond. SIHP -4643 measured 11 m N/S by 2.5 m E/W (Jackson et al. 1993:21).

Trenching and coring were also conducted within Nu‘upia Fishpond to aid in determining the construction date of the pond. Radiocarbon dating was conducted on three marine shell samples from basal strata since an insufficient amount of charcoal was recovered during subsurface testing. Calibrated date results are: 1430 to 880 BC (Beta-61547), 940 to 360 BC (Beta-61548), and AD 250 to 720 (Beta-61549). Jackson et al. (1993:78) suggest that the date results indicate “the demise of shellfish in the current pond setting may have occurred as more than one event. These data can be interpreted to indicate periodic demise of shellfish over a span of some 2150 years.” The “antiquity” of the dates suggests that the dates are unrelated to the fishpond construction (Jackson et al. 1993:65).

3.3.3.3 Final EA for Disinfection Facility Kailua Regional Wastewater Treatment Plan

A Final Environmental Assessment for the Disinfection Facility Kailua Regional Wastewater Treatment Plan TMK: 4-4-11:81 was completed in 1996. The section (6.11) on Archaeological and Historic Sites states, “No known historic or archeological sites are located within the treatment facility property boundaries …. in operation since 1967” (M&E Pacific, Inc. 1996:6).

3.3.4 Human Burials Found Within the Vicinity of the Project Area

Mōkapu Peninsula has been the focus of archaeological research over the years owing primarily to its extensive pre-contact Hawaiian sand dune burial zones. To date, it still contains the most extensive burial area known in the Hawaiian Islands and is one of the largest in the Pacific. Additionally, burials have been recovered within the sandy shoreline areas of Kailua, which was used extensively for burial of the dead. These burial remains, however, are typically not as dense as the hundreds of human burials discovered from Mōkapu peninsula (Snow 1974).

Table 4 provides data related to burials found within the vicinity of the project area, as well as their distance from the current project.

Table 4. Summary of Human Burials Reported within the Vicinity of the Project Area

Reference	SIHP # (50-80-11-)	TMK	Findings and Distance from Project Area
Snow 1974 Bowen 1974 Tuggle and Hommon 1986	1017	Mokapu Burial Area in Kāne‘ohe and He‘eia *ahupua‘a*	1938 - Kenneth Emory conducted first archaeological investigation; findings included 40 burials with associated cultural material including a necklace, dog teeth, 87 land snails, and a cone shell. Since the early 20th century, findings have totaled almost 1,500 sets of pre-contact and early historic human remains, some of which were associated with *lei niho palaoa*, shell fishhooks, mats, *tapa* cloth, octopus lure hook, and lithics. Bird, pig, and dog burials have also been found associated with human remains. Approximately 2.9 km north of Kailua WWTP
Davis 1976	1002	Ulupa‘u Dune	24 burials of various ages and both sexes in close proximity with almost 100 firepits and 12 postholes. Approximately 2.0 km northeast of Kailua WWTP
Davis et al. 1976	1002	Ulupa‘u Dune	Cultural deposit within Ulupa‘u Dune was approximately 30 m wide; 89 burials disinterred – single and multiple interments of various ages and both sexes. Postholes, midden material, and earthen ovens found in close proximity to burials. Approximately 1.5 km northeast of Kailua WWTP

Reference	SIHP # (50-80-11-)	TMK	Findings and Distance from Project Area
Clark and Riford 1986	2937	4-5-30:43	Two fully extended burials lacking historic grave goods, and fragmented skeletal remains found within four test pits. Approximately 450 m west of Kāne‘ohe WWPTF
Bath 1989 Pietruewsky 1989	3993	4-3-22:11	Single burial recovered within an area that had previously been the shoreline. Pig tusks and vertebrae also found in close proximity; osteological analysis completed. Approximately 900 m east of Kailua WWTP
Jourdane 1993	4691	4-4-39:015	Human skeletal remains were inadvertently discovered on the beach. Wave action exposed human remains that were believed to be one individual most likely of Hawaiian ancestry. Approximately 1.6 km east of Kailua WWTP
Putzi 1996	5377	4-3-26:43	Human skeletal remains were discovered during the installation of a new swimming pool. Two in situ burials, and two individuals were recovered from the back dirt piles. All four individuals are believed to be of Native Hawaiian ancestry. Approximately 2.4 km southwest of Kailua WWTP
Putzi and Dye 2004	6642	4–3–22:11	Traditional Hawaiian habitation with five early historic-era human burials and one pig burial. Dating was based on presence of glass beads in association with one burial. Approximately 800 m southeast of Kailua WWTP
Borthwick et al. 2006	6770, 6818	4-3-016, 017-020, 024-027, 075, 080	Two separate inadvertent burial discoveries were made on Kalāheo Avenue during trenching for a new sewer line installation. SIHP # -6670 is approximately 1.7 km southeast of Kailua WWTP; SIHP # -6818 is approximately 2.1 km southeast of Kailua WWTP
Whitman and Hammatt 2008	6925	4-3-083:057	A disarticulated human burial, determined to be one individual, was found within previously disturbed Jaucus sand during excavations for the existing sewer line. The remains may have been buried within the project area or imported from elsewhere. Approximately 900 m southeast of Kailua WWTP

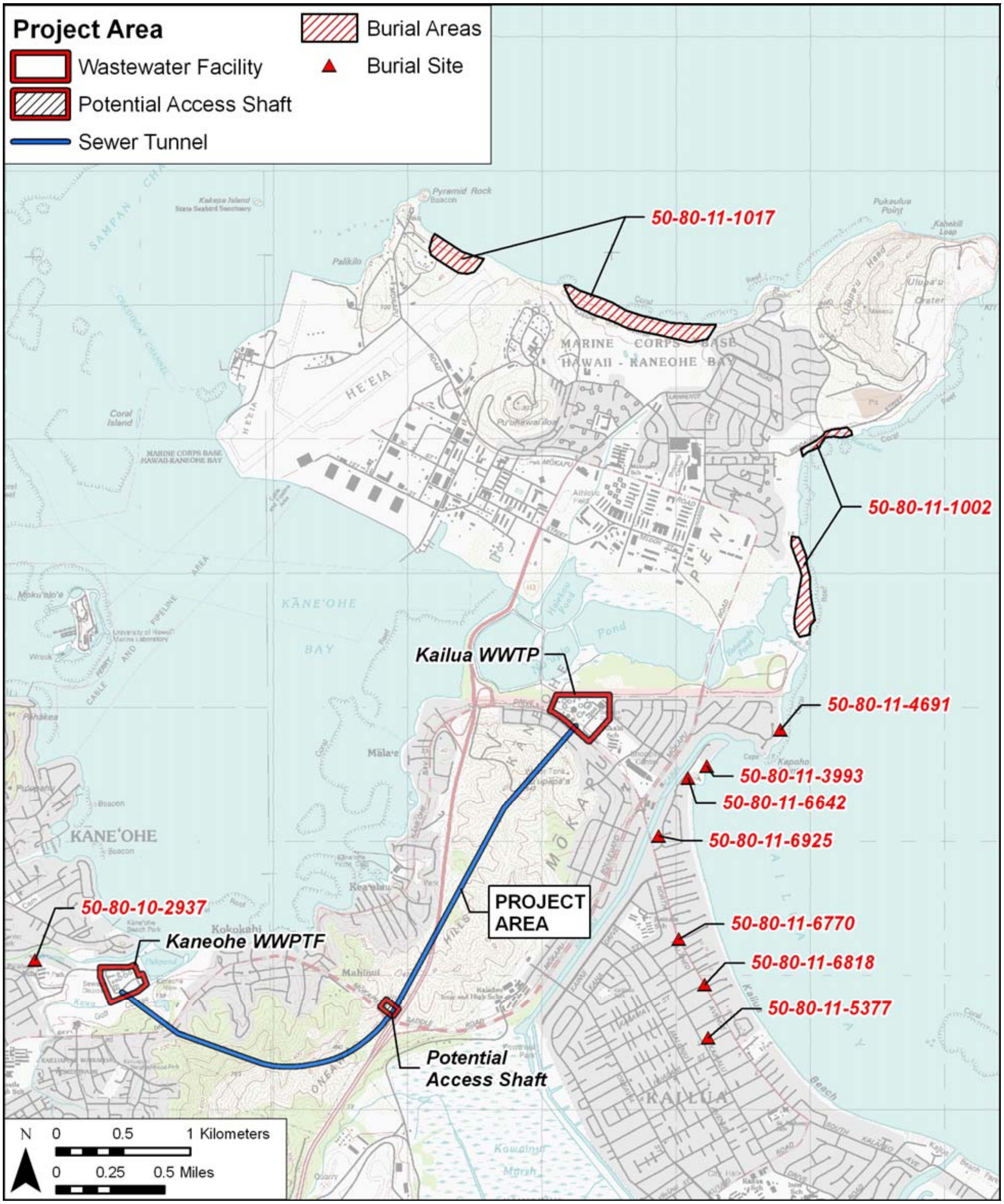

Figure 22. Portion of U.S. Geological Survey 7.5-Minute Series Topographic Map, Kaneohe (1998) and Mokapu Point (1998) quadrangles, showing locations of previously identified human remains found within the vicinity of the project area

Section 4 Results of Fieldwork

4.1 Survey Findings

CSH archaeologist, Randy Groza, M.A. and cultural specialist Joe Genz, Ph.D. completed the field inspection on August 24, 2010, which required one person-day. All fieldwork was conducted under CSH’s annual Archaeological Permit No. 10-10 issued by SHPD per HAR Chapter 13-282, and also under the general supervision of Hallett H. Hammatt, Ph.D. (principal investigator).

The field inspection consisted of a pedestrian inspection of the three different portions of the proposed project, Kāne‘ohe Wastewater Pre-Treatment Facility (WWPTF), the Kailua Regional Wastewater Treatment Plant (WWTP), and the intermediate tunnel access shaft just northwest of Mōkapu Saddle Road at its intersection with Interstate H-3. No access restrictions impeded the inspections, however, ground visibility is obstructed by previous development. No historic properties or cultural materials were observed during the field inspection. Field inspection summaries and photograph documentation for each of the three areas is presented below.

4.2 Kāne‘ohe Wastewater Pre-Treatment Facility (WWPTF)

Kāne‘ohe WWPTF is fenced, and bordered by undeveloped City and County of Honolulu property to the south and west, and a roadway to the north that leads to a parking lot, houses, and Waikalua Loko, that are to the east of WWPTF. Approximately 60 percent of WWPTF is currently developed as shown on a recent aerial (Figure 23; Google 2009) that also has an overlay showing the likely locations of improvements for the facility. These areas currently contain various tanks and above surface piping with grasses and gravel between the tanks.

An asphalt road extends through the WWPTF entrance into the facility past existing tanks (Figure 24). Figure 25 is an overview of the project area with tanks in the foreground and Waikalua Loko in the background. Figure 26 and Figure 27 are photographs of the existing holding tanks situated in the western portion of WWPTF and in an area of planned improvements. Figure 28 shows the surface piping extending between the tanks with some vegetation and gravel for ground cover.

A dirt road extends along the facility’s northern boundary with fairly dense vegetation along the boundary fencing (Figure 29). The fencing and vegetation separate WWPTF from the above mentioned roadway leading to an adjacent parking lot, houses, and Waikalua Loko.

The eastern portion of WWPTF does not contain as much development as the western, however, various buildings and tanks cover more than half of this portion, as shown in Figure 30 through Figure 32.

Figure 23. Kāne‘ohe WWPTF, showing likely locations of improvements and the extent of previous development within the area (source: Google 2009, provided by client)

Figure 24. Entrance to the Kāne‘ohe WWPTF, showing chain link fencing along southern boundary to right and existing tanks where improvements are planned to left of asphalt paved roadway, view to southeast

Figure 25. Overview of Kāne‘ohe WWPTF showing area where improvements are planned, Waikalua Loko in background, view to northeast

Figure 26. Photograph showing large holding tanks where improvements are planned in central portion of the Kāne'ohe WWPTF, view to southeast

Figure 27. Photograph showing large holding tanks where improvements are planned in south central portion of the Kāne'ohe WWPTF, view to southeast

Figure 28. Photograph showing piping extending between Kāne‘ohe WWPTF tanks, view to west

Figure 29. Photograph showing northern boundary of Kāne‘ohe WWPTF, note fairly dense vegetation along fencing to right, view to west

Figure 30. Buildings and piping within eastern portion of WWPTF, view to southeast

Figure 31. Additional buildings within eastern portion of WWPTF, view to northwest

Figure 32. Photograph showing development in eastern portion of WWPTF, view to southeast

4.3 Kailua Regional Wastewater Treatment Plant (WWTP)

The Kailua WWTP is fenced, and bordered by Kāne‘ohe Bay Marine Corps Base facility to the north and west, Kāne‘ohe Bay Drive and the ‘Aikahi Gardens townhouse complex to the southwest, ‘Aikahi Park and ‘Aikahi Elementary School to the southeast, and ‘Aikahi Park residences to the east. Most of WWTP is currently developed as shown on three recent aerials (Figure 33 through Figure 35) with overlays showing possible locations of improvements for the facility. A plan for the most likely location of the dewatering facility is also included (Figure 36). Most of the areas planned for development currently contain various tanks, buildings, and other structures.

Photographs showing the existing conditions in areas proposed for improvements follow Figure 36. Figure 37 is an overview showing the general location of the flow equalization basin (also shown on aerial, Figure 33). Figure 38 through Figure 40 show three alternative locations for the new dewatering building (Alternative A through C; also shown on aerial, Figure 34). Alternative B (Figure 39) is the only location that does not appear to have been previously developed. More recent plans (Figure 36) show the most likely location of the dewatering building (Figure 47). Figure 41 through Figure 48 show the eight possible facility locations to be evaluated (also shown on aerial, Figure 35). Facility 2 (Figure 42) does not appear to have been previously developed, and portions of Facility 6 (Figure 46) may not have been previously developed, although the location does contain various utilities piping. Facility 3 (Figure 43), currently used for parking, contains a mounded area that is actually a push-pile consisting of compacted soil and debris.

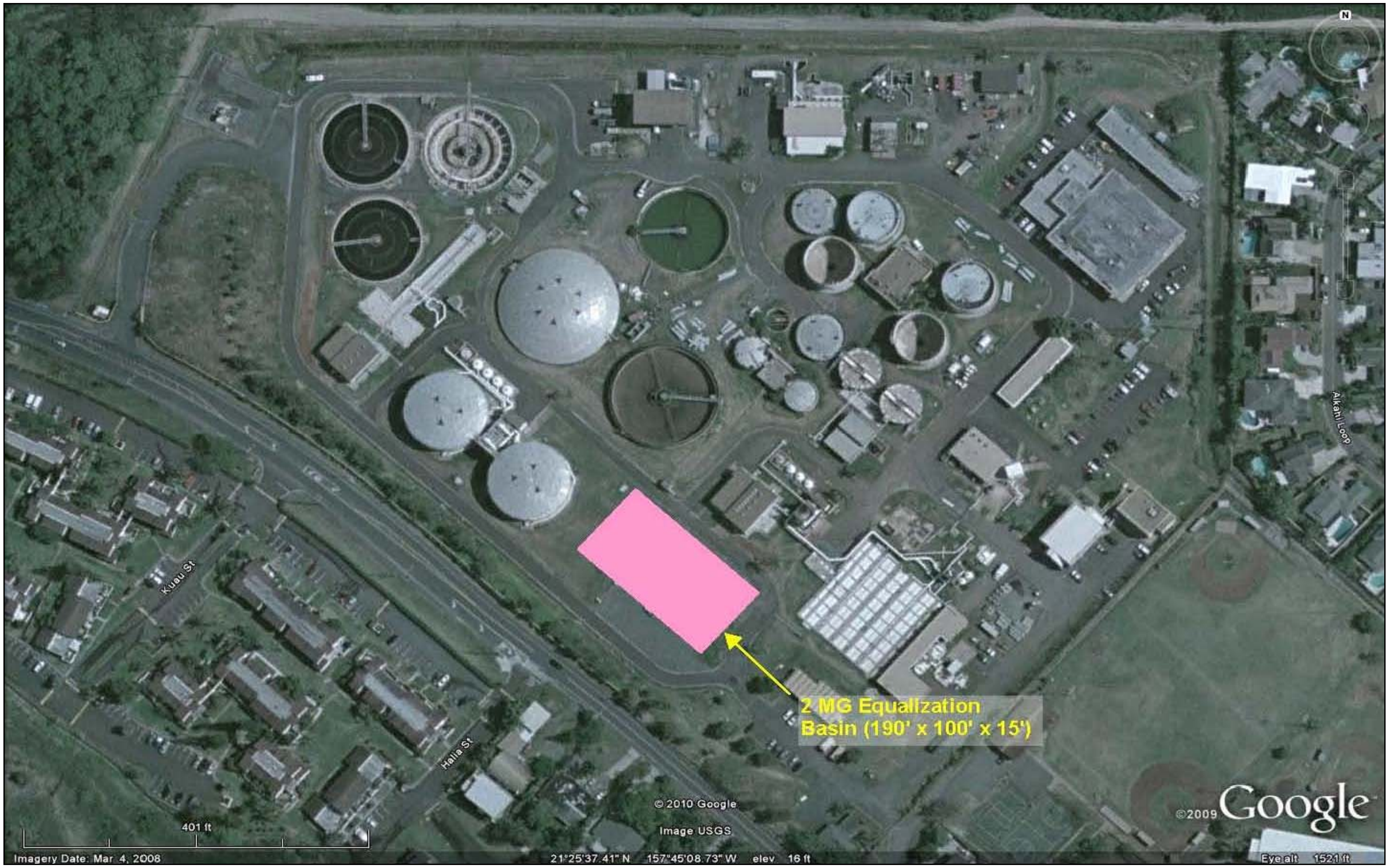

Figure 33. Kailua WWTP, showing likely location of equalization basin improvements and the extent of previous development within the area (source: Google 2010, provided by client)

Figure 34. Alternative locations for the new dewatering building at the Kailua WWTP (source: Google 2010, provided by client)

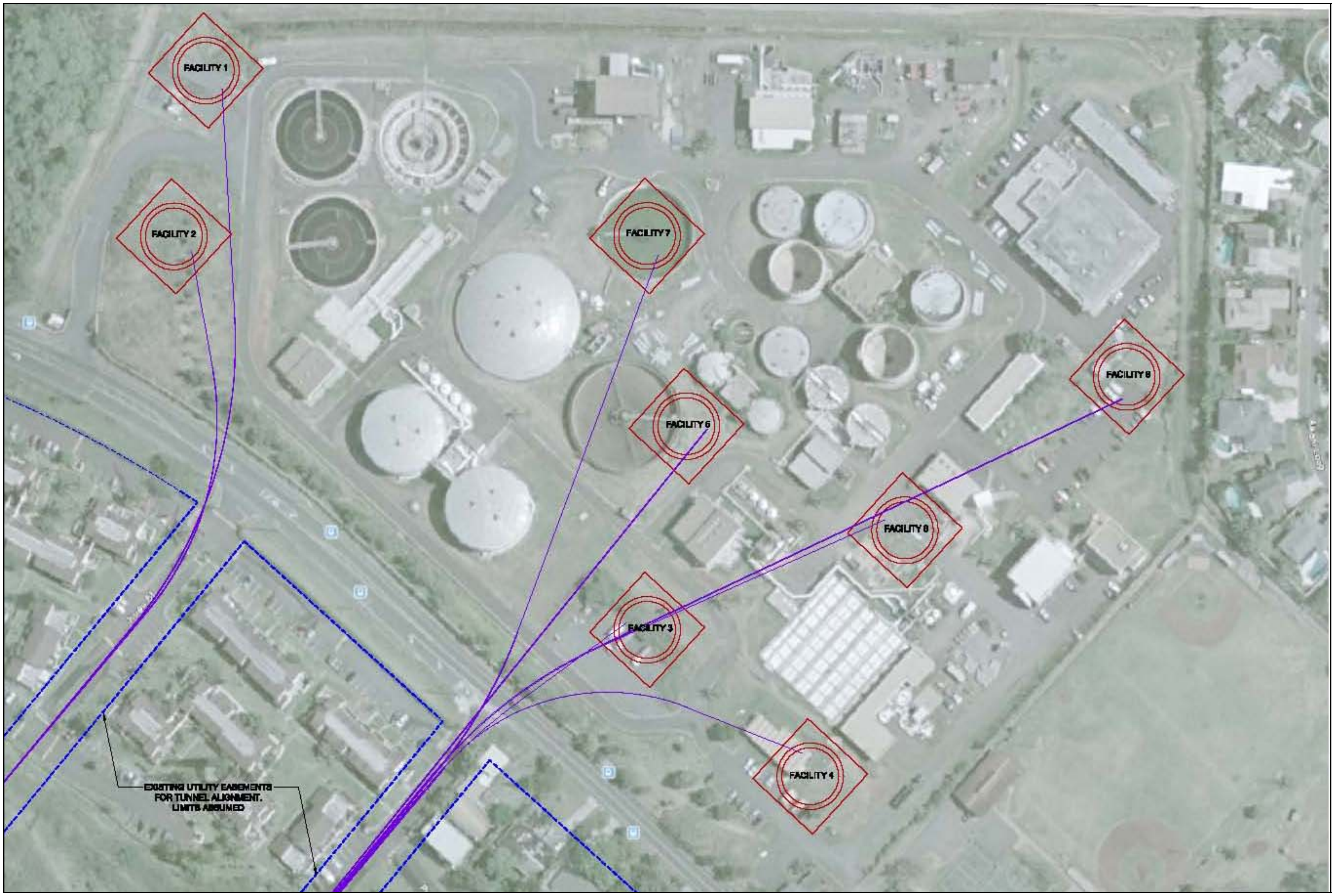

Figure 35. Eight facility locations to be evaluated at the Kailua WWTP (source: provided by client)

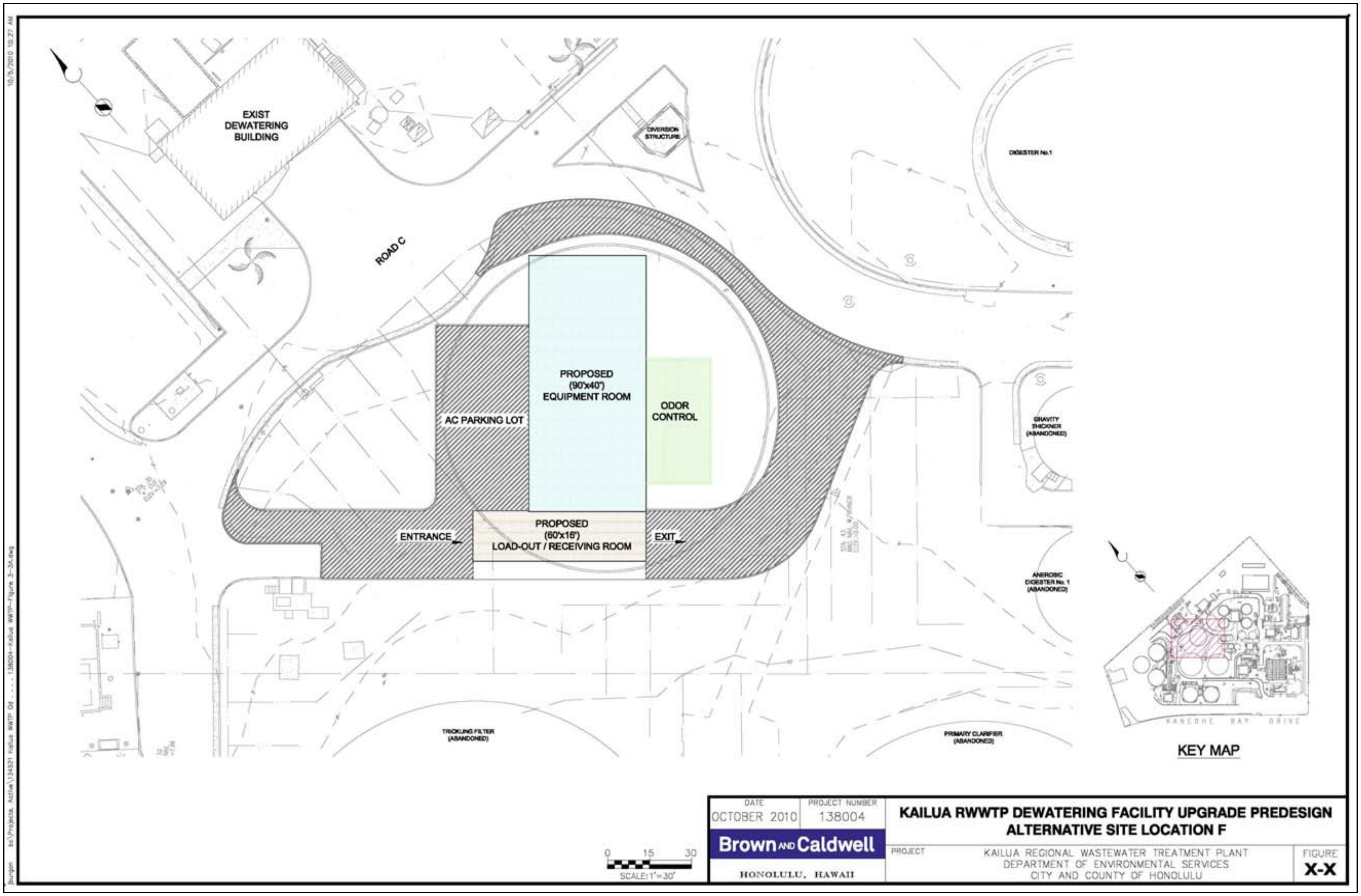

Figure 36. Plan for most likely location of dewatering facility (provided by client)

Figure 37. Overview showing proposed location of flow equalization basin at the Kailua WWTP, view to southeast (also shown on aerial, Figure 33 and a second photograph Figure 43)

Figure 38. Site location Alternative A at the Kailua WWTP, view to north

Figure 39. Site location Alternative B at the Kailua WWTP, view to northeast

Figure 40. Site location Alternative C at the Kailua WWTP, view to east

Figure 41. Overview showing location of “Facility 1” at the Kailua WWTP, view to west

Figure 42. Overview showing location of “Facility 2” at the Kailua WWTP, view to west

Figure 43. Overview showing location of "Facility 3" at the Kailua WWTP, view to southwest. Note that mounded area consists of compacted soil and debris. This location is also proposed for the equalization basin (see Figure 33).

Figure 44. Overview showing location of "Facility 4" at the Kailua WWTP, view to northwest

Figure 45. Overview showing location of "Facility 5" at the Kailua WWTP, view to northwest

Figure 46. Overview showing location of "Facility 6" at the Kailua WWTP, view to northeast

Figure 47. Overview showing location of "Facility 7" at the Kailua WWTP, view to southwest This is also the most likely location of the dewatering facility.

Figure 48. Overview showing location of "Facility 8" at the Kailua WWTP, view to southwest

4.4 Tunnel Access Shaft

The proposed location of the intermediate tunnel access shaft is within a fenced, approximately 1.6-acre parcel that is bordered by undeveloped privately owned land to the north and west, Mōkapu Saddle Road to the south, and Interstate H-3 to the east (Figure 49). The parcel, owned by the Board of Water (BWS), currently contains a water tank, construction debris, piping, and soils for / from BWS projects (Figure 50 and Figure 51). The preferred location for the tunnel access shaft is a flat area like the northeast corner of the parcel (Figure 51). The portion of the parcel just east of the water tank is flat and open, however, HECO has construction plans for that area (Figure 52). The easternmost portion of this area may be usable (Figure 52 and Figure 53). The parcel's north boundary is sloped and the northwestern portion of the parcel extends up hill and is covered with *koa haole* (*Leucaena leucocephala*) and grasses (Figure 54). This is not an area under consideration for the tunnel access shaft.

Figure 49. Photograph showing location of water tank within the BWS property and location of proposed intermediate tunnel access shaft, Mōkapu Saddle Road in foreground, view to north

Figure 50. Photograph showing existing water tank, southern fenced boundary of parcel, BWS property at Mōkapu Saddle Road, showing construction debris, piping and gravel, view to west

Figure 51. Northeast portion of parcel, BWS property at Mōkapu Saddle Road, showing soil push-piles, and piping, potential area for access tunnel, view to north

Figure 52. Flat, undeveloped area just east of water tank, BWS property at Mōkapu Saddle Road, view to southeast

Figure 53. Area east of water tank, BWS property at Mōkapu Saddle Road, and possible location for tunnel access shaft

Figure 54. Photograph showing *koa haole* and grasses covering hillside in northwest portion of parcel, BWS property at Mōkapu Saddle Road, view to southeast

Section 5 Summary and Recommendations

5.1 Summary

No surface historic properties were identified within the Kāne‘ohe Wastewater Pre-Treatment Facility (WWPTF), Kailua Wastewater Treatment Plant (WWTP), and a proposed tunnel access shaft location within BWS lands northwest of Mōkapu Saddle Road at its intersection with Interstate H-3 during the field inspection for Alternative 2 of the project plans. Kāne‘ohe WWPTF and Kailua WWTP were both observed to have undergone extensive land modification associated with sewer and water treatment and their related facilities. BWS lands in the vicinity of the proposed tunnel access shaft contain a large water tank, construction debris, piping, and soils for / from BWS projects. Geotechnical testing results (see Appendix A) show that basalt extends from 61 cm below surface (2 feet) to the bottom of the excavation, 98 m below surface (320.5 feet).

Despite the lack of surface findings, subsurface historic properties may be present within Kāne‘ohe WWPTF lands. This location was something of a quilt of traditional Hawaiian habitations and taro patches as documented in the 19 circa 1848 Land Commission Awards (see Figure 10, Figure 12, and Table 1). This pattern of intensive habitation and intensive traditional Hawaiian agriculture may have existed for centuries prior to Western contact in this area of unique natural abundance bordered by perennial Kawa Stream to the south and the rich margins of Kāne‘ohe Bay to the east. Perennial Kāne‘ohe Stream was approximately 60 m to the north.

Limited subsurface testing was previously conducted adjacent to Kāne‘ohe WWPTF lands (Hammatt and Borthwick 1989). A series of eight 20-ft. to 25-ft. trenches was undertaken in a relatively small portion of land along the west boundary of the sewage treatment plant on the north side of Kawa Stream. No cultural materials or features were discerned. No sign of an *‘auwai* or earthen field boundaries believed to have been in the immediate vicinity were discerned.

A small area in northeastern portion of Kailua WWTP contains Jaucas sand (see Figure 7). Human burials have been found throughout the Hawaiian Islands within Jaucas sand deposits.

No previous archaeological studies have found historic properties and human burial remains within close proximity to the proposed project areas.

5.2 Recommendations

After the City and County of Honolulu and the EPA determine the most appropriate alternative plan for this project, CSH recommends the following if Alternative 2, the gravity tunnel, is chosen. These recommendations are based on the results of the literature review and field inspection.

5.2.1 Kāne‘ohe WWPTF

A program of archaeological inventory survey subsurface testing is recommended in consultation with SHPD that is based on project plans and scaled to address the specific locations of planned excavations.

Based on the findings of the archaeological inventory survey and in consultation with SHPD, monitoring is likely to be appropriate during initial subsurface excavations within Kāne‘ohe WWPTF.

5.2.2 Waikalua Loko Fishpond

Project activities related to the proposed Kāne‘ohe WWPTF upgrades should avoid direct or indirect adverse impacts to Waikalua Loko Fishpond (SIHP # 50-80-10-349) and its vicinity (TMK: [1] 4-5-030:001, por.). Consultation with SHPD and the Waikalua Loko Fishpond Preservation Society and consideration of the Waikalua Loko Fishpond Preservation Plan (Dasheill 1995) is recommended if construction staging or other activities are planned within the fishpond's vicinity.

5.2.3 Kailua WWTP

Jaucus sand (see Figure 7) is present within a very small area in the vicinity of the Kailua WWTP administration building in the northeastern portion of Kailua WWTP. Human burials have been found throughout the Hawaiian Islands within Jaucas sand deposits. Currently, no new facilities are planned in this area. If any subsurface disturbance is planned for this area, a program of archaeological inventory survey subsurface testing is recommended in consultation with SHPD. Based on the findings of the archaeological inventory survey and in consultation with SHPD, monitoring is likely to be appropriate during subsurface excavations within the northeast portion of Kailua WWTP.

Otherwise, no further work is recommended for Kailua WWTP based on historic research, extensive development within the project area, and the lack of previous findings within the facility.

5.2.4 Nu‘upia Fishpond

Nu‘upia Fishpond is within Marine Corps Base Hawaii, and no adverse affects to the fishpond are anticipated as a result of the proposed project.

5.2.5 Proposed Tunnel Access Shaft Location

No further work is recommended for the proposed tunnel access shaft location within BWS lands northwest of Mōkapu Saddle Road at its intersection with Interstate H-3 based on geotechnical testing results showing basalt extending from 61 cm below surface (2 feet) to 98 m below surface (320.5 feet; see Appendix A).

If, however, a new location for the proposed tunnel access shaft is identified, additional literature review and field inspection is recommended.

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Appendix A Geotechnical Boring Logs

GEOLABS, INC. Geotechnical Engineering	K2K	Log of Boring 22

Approximate Ground Surface Elevation (feet MSL): 242 *

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
										GM	Brownish gray **SILTY GRAVEL** with cobbles, dense, damp (colluvium - talus deposit)
			100	61							Gray dense **BASALT** with xenoliths and xenocrystals, slightly fractured, unweathered to slightly weathered, very hard (volcanic dike / batholith complex)
							5				
			100	65							
											grades with multi-color inclusions
							10				grades massive locally
			100	100							
							15				
			100	65							
							20				
			100	70							
							25				grades to slightly fractured
			100	87							
							30				
			100	100							
											grades to massive
							35				

Date Started:	May 5, 2010	Water Level: ∇	Dry 05/17/2010 0755 HRS	Plate
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS	
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75	A - .1
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring	
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC. Geotechnical Engineering	K2K	Log of Boring 22

Laboratory			Field								(Continued from previous plate)
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			100	97							
							40				
			98	68							
							45				
			95	73							
							50				
			100	98							
							55				
			100	100							
							60				
			100	100							
							65				
			100	100							
							70				

Date Started:	May 5, 2010	Water Level: ∇	Dry 05/17/2010 0755 HRS	Plate
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS	
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75	A - .2
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring	
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC.

Geotechnical Engineering

K2K

Log of Boring

22

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
											(Continued from previous plate)
			100	100							
							75				
			100	100							
							80				
			100	100							
							85				
			100	90							
							90				
			98	87							
							95				
			100	97							
							100				
			100	73							
							105				

Date Started:	May 5, 2010	Water Level: ▽	Dry 05/17/2010 0755 HRS	Plate
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS	
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75	
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring	A - .3
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC.

Geotechnical Engineering

K2K

Log of Boring

22

(Continued from previous plate)

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			100	63							
							110				
			100	100							
							115				
			100	100							
							120				
			100	100							
							125				
			100	100							
							130				
			100	100							
							135				
			100	82							
							140				

Date Started:	May 5, 2010	Water Level: ⊽	Dry 05/17/2010 0755 HRS	Plate
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS	
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75	A - .4
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring	
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC. Geotechnical Engineering	K2K	Log of Boring 22

(Continued from previous plate)

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			100	100							
							145				
			100	100							
							150				
			100	100							
							155				
			100	100							
							160				
			100	92							
							165				
			100	72							
							170				
			100	100							
							175				

Date Started:	May 5, 2010	Water Level: ⊻	Dry 05/17/2010 0755 HRS	Plate
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS	
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75	A - .5
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring	
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC. Geotechnical Engineering	K2K	Log of Boring 22

Other Tests (Laboratory)	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%) (Field)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description (Continued from previous plate)
			100	100							
							180				
			100	63							grades to moderately fractured
							185				
			97	30							
							190				
			97	28							
							195				Brownish gray **BASALT**, closely to moderately fractured, moderately weathered, medium hard to hard (country rock)
			90	0							
											grades with brown clay in fractures
							200				
			100	63							Gray dense **BASALT**, closely to moderately fractured, moderately to slightly weathered, hard
							205				
			97	32							
							210				

DRAFT 08/06/2010

Date Started:	May 5, 2010	Water Level: ⊻	Dry 05/17/2010 0755 HRS	Plate
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS	
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75	A - .6
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring	
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC.

Geotechnical Engineering

K2K

Log of Boring **22**

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
											(Continued from previous plate)
			100	22							
							215				
			80	7							Brown to brownish gray **BASALT**, closely fractured, moderately to highly weathered with clay seams, soft to medium hard with hard zones
							220				
			50	27							
											Bluish gray with brown mottling **BASALT**, closely to slightly fractured, slightly to moderately weathered, hard
							225				
			100	27							Gray with brown and gray mottling **BASALT**, closely to moderately fractured, moderately weathered, hard
							230				
			100	23							Brown **BASALT**, moderately to closely fractured, moderately weathered with brown clay inseam from 231.7 to 232 feet
											Brownish gray **BASALT** with some clay seams, closely to moderately fractured, slightly to moderately weathered, medium hard to hard
							235				
			100	7							
											grades to brownish gray and closely fractured locally
							240				
			100	25							
							245				

Date Started:	May 5, 2010	Water Level: ⊻	Dry 05/17/2010 0755 HRS
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop

Plate A - .7

GEOLABS, INC.

Geotechnical Engineering

K2K

Log of Boring **22**

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
											(Continued from previous plate)
			100	7							
							250				
			82	22							
							255				
			93	37							Gray dense **BASALT**, moderately fractured, slightly weathered, hard to very hard
							260				
			100	29							
							265				
			8	0							Grayish brown **BASALT**, severely fractured, highly weathered, soft to medium hard
							270				Brownish gray dense **BASALT**, closely fractured, slightly weathered, hard to very hard
			72	0	50/2" Ref.						
							275				
			83	17							
			80	0							
							280				

Date Started:	May 5, 2010	Water Level: ∇	Dry 05/17/2010 0755 HRS
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop

Plate

A - .8

GEOLABS, INC. Geotechnical Engineering	K2K	Log of Boring 22

Laboratory			Field								(Continued from previous plate)
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			43	15							
			79	17			285				
			100	81							Gray **BASALT**, moderately fractured, slightly weathered, very hard
							290				
			100	42							
			100	100							grades to massive
							295				
			73	50							Bluish gray with brown and green mottling **BASALT**, moderately fractured, slightly weathered, hard to very hard
							300				
			100	100							grades to massive
							305				
			100	100							
							310				
			100	67							
							315				

Date Started:	May 5, 2010	Water Level: ∇	Dry 05/17/2010 0755 HRS	Plate
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS	
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75	A - .9
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring	
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC. Geotechnical Engineering	K2K	Log of Boring 22

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description (Continued from previous plate)
			100	62							
							320				Boring terminated at 320.5 feet
							325				
							330				
							335				
							340				
							345				
							350				

DRAFT 08/06/2010

Date Started:	May 5, 2010	Water Level: ∇	Dry 05/17/2010 0755 HRS	Plate
Date Completed:	June 4, 2010		209.5 ft. 06/02/2010 0715 HRS	
Logged By:	Aczon, Latronic & Nolasco	Drill Rig:	CME-75	
Total Depth:	320.5 feet	Drilling Method:	4" Auger, 5" Casing & PQ Coring	A - .10
Work Order:	6174-10	Driving Energy:	140 lb. wt., 30 in. drop	

Appendix G

Cultural Impact Assessment:
Proposed Kaneohe – Kailua Force Main No. 2
Kaneohe, Koolaupoko, Oahu
Aki Sinoto Consulting LLC
December 2010

ASC120510

CULTURAL IMPACT ASSESSMENT:

PROPOSED KANE`OHE-KAILUA FORCE MAIN NO. 2
KANE`OHE, KO`OLAUPOKO, O`AHU

December 2010

Aki Sinoto Consulting, LLC
2333 Kapiolani Blvd., No. 2704
Honolulu, Hawai`i 96826

ASC120510

CULTURAL IMPACT ASSESSMENT:

PROPOSED KANE`OHE-KAILUA FORCE MAIN NO. 2
KANE`OHE, KO`OLAUPOKO, O`AHU

for

Austin, Tsutsumi and Associates, Inc.
501 Sumner Street, Suite 521
Honolulu, Hawai`i 96817-5031

by

Melissa Lehuanani Ka`akau-Delizo

Moana L.J. Lee

and

Aki Sinoto

December 2010

Aki Sinoto Consulting
2333 Kapiolani Blvd., No. 2704
Honolulu, Hawai`i 96826

ABSTRACT

A cultural impact assessment, including a review of pertinent previous studies, archival documents, historic aerials, and maps, together with oral interviews, was undertaken by Aki Sinoto Consulting of Honolulu at the request of Austin Tsutsumi and Associates, Inc. (ATA), also of Honolulu. This assessment report was prepared in conjunction with an environmental impact statement (EIS) being prepared by the City and County of Honolulu (CCH) for the proposed Kane`ohe/Kailua Force Main Number 2 (KKFM2) Project. The proposed undertaking, mandated by a 1995 Federal Environmental Protection Agency consent decree seeks to connect the existing Kane`ohe Effluent Pump Station (KEPS) in Waikalua to the existing Kailua Regional Waste-water Treatment Plant (KRWTP) in Aikahi via a transmission pipeline traversing under the sea floor of Kane`ohe Bay. The construction will employ Horizontal Directional Drilling (HDD) and/or Micro-tunneling technologies to install roughly 10,845 linear feet (3,305.55 m) of jacketed pipeline, down to 80 feet (24.38 m) deep, under the bottom of the bay along with a total of 4,069 linear feet (1,240.23 m) of land segments at both ends of the under-bay line.

Pertinent previous reports, archival documents, historic maps, and aerial photographs obtained through search efforts were reviewed and analyzed. Historic background summaries for different time periods were compiled, specific reference materials were reviewed for pertinent information included in this report. Interviews with six individuals were undertaken and summary of each interview is presented together with a resulting summary discussion. Additionally, attendance and participation in informational briefings and community meetings afforded opportunities to consult with a broad range of the community. Proactive consultation early in the planning process with the State Historic Preservation Division, the O`ahu Island Burial Council, and area community groups were undertaken and coordination with some are on-going.

Community concerns primarily focused on restricted marine traffic within the bay. However, these concerns were alleviated when no over-water structures, floating pipes, or other obstructions were determined to be required on the surface of the bay other than for emergencies.

Thus, the results of the current assessment procedure strongly suggest that no adverse impacts to traditional or contemporary cultural practices will be brought about by the implementation of the proposed Kane`ohe/Kailua Force Main No. 2 Project.

An archaeological assessment report was prepared under separate cover and shall be included in the EIS as a technical appendix.

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INTRODUCTION

At the request of Austin Tsutsumi and Associates, Inc. of Honolulu; Aki Sinoto Consulting of Honolulu, undertook a cultural impact assessment in conjunction with the Kane`ohe-Kailua Force Main No. 2 (KKFM2) Project being proposed by the City and County of Honolulu (CCH). The proposed project seeks to connect the existing Kane`ohe Effluent Pump Station (KEPS) in Waikalua with the existing Kailua Regional Wastewater Treatment Plant (KRWTP) in Aikahi via a new force main waste-water transmission line traversing under the bottom of Kane`ohe Bay (Figs. 1 & 2). A background description of the project region, a summary of pertinent information obtained from a review of literature and archival search of historic maps and documents, summaries of interviews conducted with selected individuals familiar with the region, and finally an assessment of the potential cultural impact posed by the proposed project are presented in this report. The current assessment followed the *Guidelines for Assessing Cultural Impacts* as adopted by the Environmental Council of the State of Hawai`i on November 19, 1997.

PROJECT REGION

Specific details regarding the KKFM2 project area have been described in an archaeological assessment report produced under separate cover (Sinoto and Titchenal 2010). The reader is referred to that report for details regarding the transmission line alignment and associated infrastructure. For the purposes of the current cultural assessment, a brief description of the region is presented in this section.

Kane'ohe *ahupua`a* comprises one of eleven traditional subdivisions of the Ko`olaupoko District of O`ahu Island and also one of nine *ahupua`a* that surround Kane`ohe Bay. The windward side of the island possesses certain geophysical and other natural attributes that make it unique in the major Hawaiian Islands. Handy and Handy (1976:432) described eight such characteristics that define this uniqueness that included climate, availability of fresh water, rich soils, inland and coastal resources, and not least the presence of the expansive sheltered embayment fronting a large portion of the windward coast. Kane'ohe has often been described in the past as the "bread basket" of O`ahu favored by the early Polynesian arrivals as well as later by various chiefs and royalty.

Kane`ohe Bay, located in the Ko`olaupoko District on the northeast coast of O`ahu Island and long been recognized as a unique marine environment with an abundance of corals and associated marine resources, is a complex estuarine system incorporating more than ten streams, an outer

Figure 1. Aerial Overview of KKFM2 Project Area

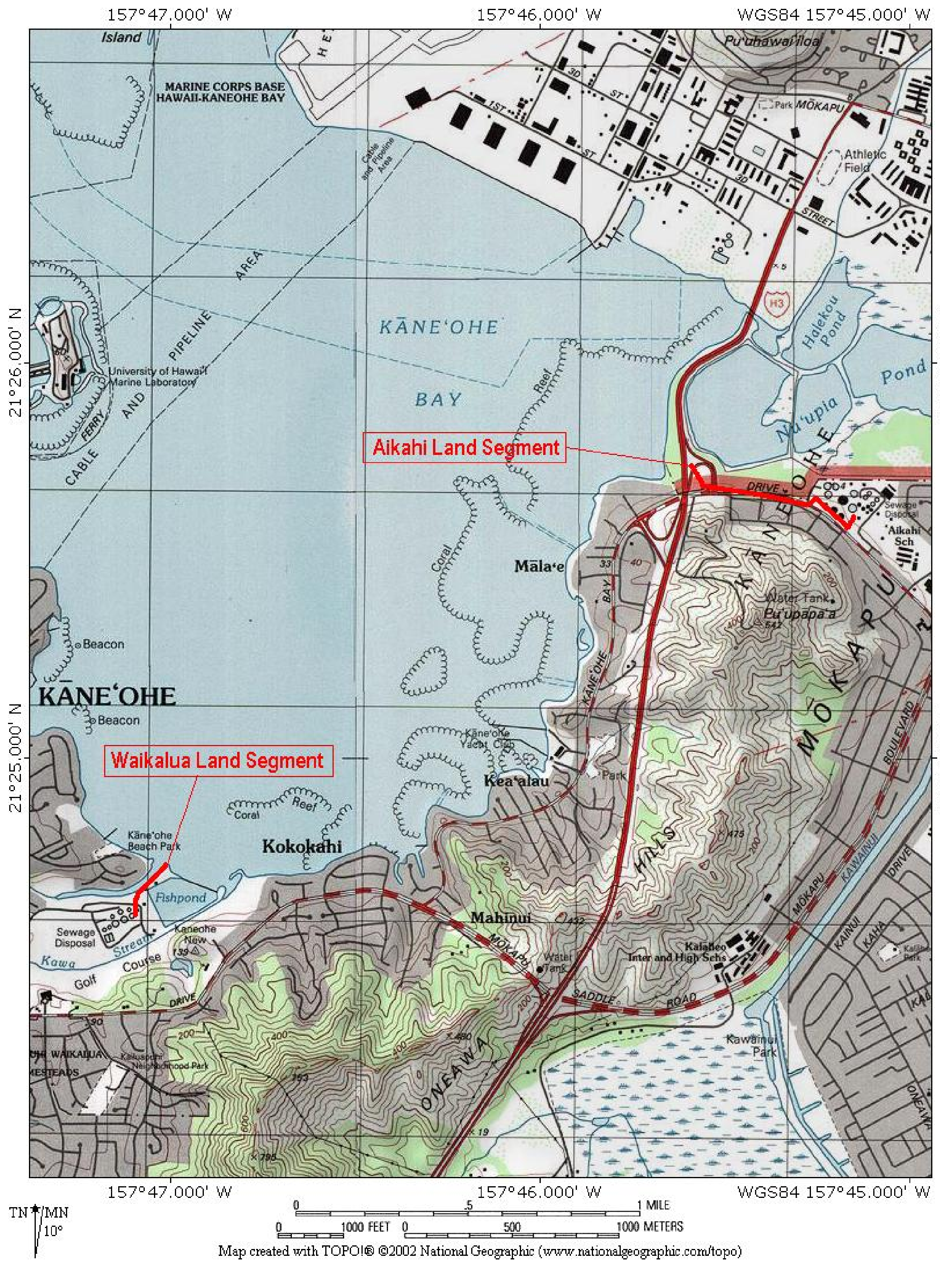

Figure 2. Locations of Both Land Segments of the Kane`ohe Kailua Force Main No. 2 Project on a Portion of the USGS Kaneohe Quadrangle

barrier reef, an intermediate lagoon with numerous patch reefs, and fringing reefs near the shoreline. It is the largest sheltered body of water in the main Hawaiian Islands encompassing a surface area of roughly 11,000 acres (4,451.7 ha) at mean sea level. One of the earliest descriptions of the bay was made by James Macrae, a botanist on Byron's 1824-1836 voyage, who stated that the open and exposed bay was "full of rocks in many places above water which renders it unsafe for vessels to anchor. It is full of fish." (Wilson 1922 in Coles et al. 2002:6). In 1928, just prior to the beginning of large-scale impacts to the bay, it was described as "one of the most favorable localities for the development of shallow water corals..." with "…nearly all the reef-forming genera known in the Hawaiian Islands…represented in certain areas of the this bay and many species growing luxuriantly." (Edmondson 1928 in Coles et al. 2002:7). Figures 3-5 show portions of early maps of the southern bay. The many adverse impacts that took place both historically and during modern times are summarized in a following section of this report.

The climate of the project region, similar to the other windward coastal areas of O`ahu, consists of 40-50 inches of annual rainfall with the highest rainfall occurring between November and March with the lowest in June and July. Frequent showers occur with the most during the early morning and evening periods. The prevailing wind is from the northeast and ranges between 4 to 24 miles per hour during trade-wind conditions over roughly half of the year. The average temperatures range between 65^{o} F to 85^{o} F; they are lower during December through March and higher during May through October. The mean tidal range measures approximately 0.68m daily (Jokiel et al. 1993).

There are five islets within Kane`ohe Bay with three; Ahu o Laka, a sand bar; Kekepa; and Kapapa that occur on the barrier reef. The other two are prominent islets within the bay; Mokoli`i and Moku o Lo`e. Mokoli`i, better known as Chinaman's Hat, is in the northern end of the bay at Kualoa. Moku o Lo`e, also known as Coconut Island and occupied by the Pauley-Pagen Marine Laboratory, is owned by the State of Hawaii and located in the southwestern part of the bay in the neighboring *ahupua`a* of He`eia..

The inner bay subdivides into three sections: the northern, central, and southern bays. Water flows from the open ocean over the reefs into the central bay then flows out through two man-made channels. A deep shipping channel, dredged between 1939 and 1945, in the northern bay and the Sampan Channel in the central part of the bay are open channels for inter-tidal flows in and out to the ocean. The southern bay is partially enclosed by Mokapu Peninsula and Moku o Lo`e and as a result, has restricted circulation with the open ocean and the rest of the bay (Fig. 6).

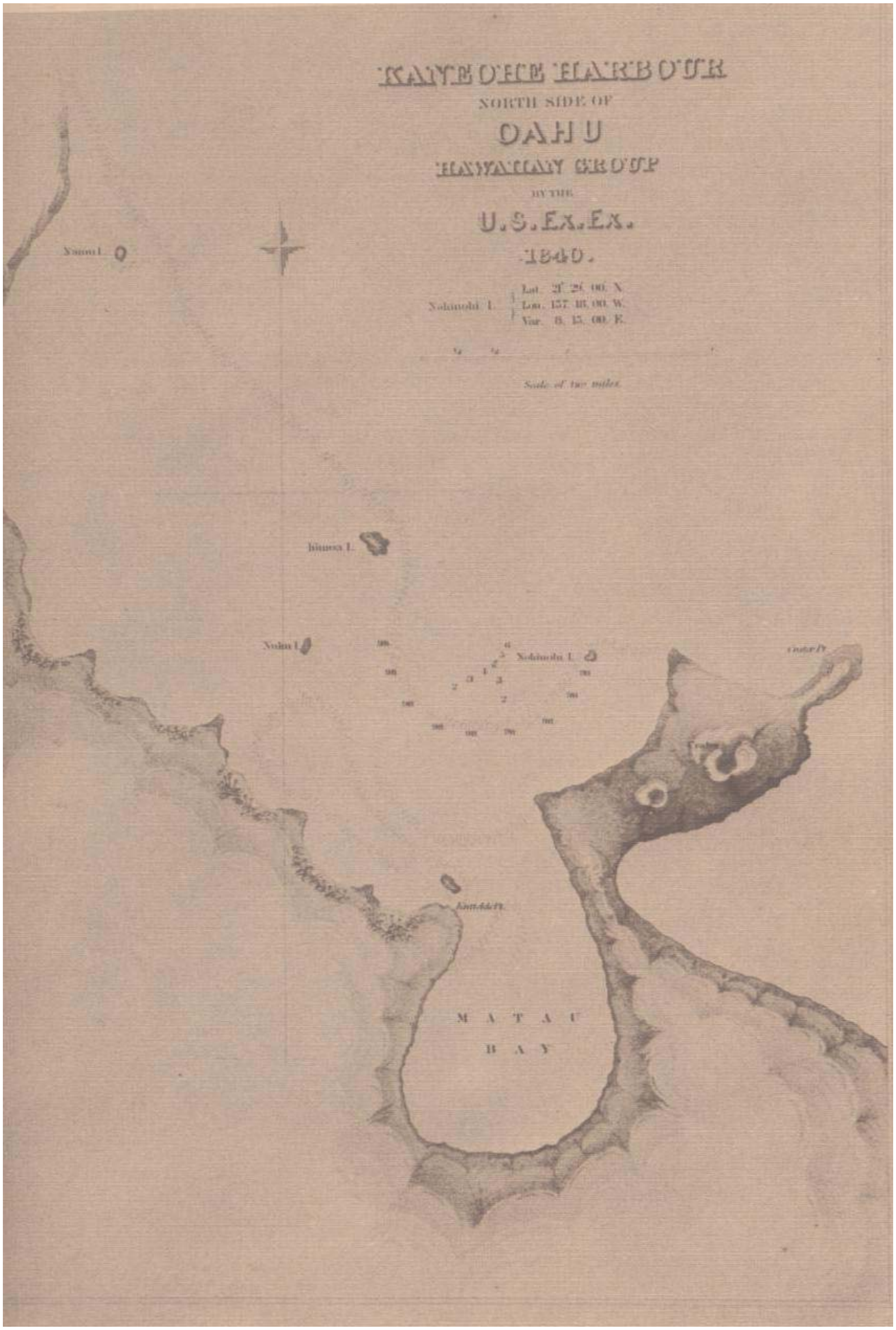

Figure 3. The First Nautical Chart of Kane`ohe Bay in 1840 by Wilkes
Note Distortion of South Bay and Mokapu Peninsula (from Devaney et al. 1976:119)

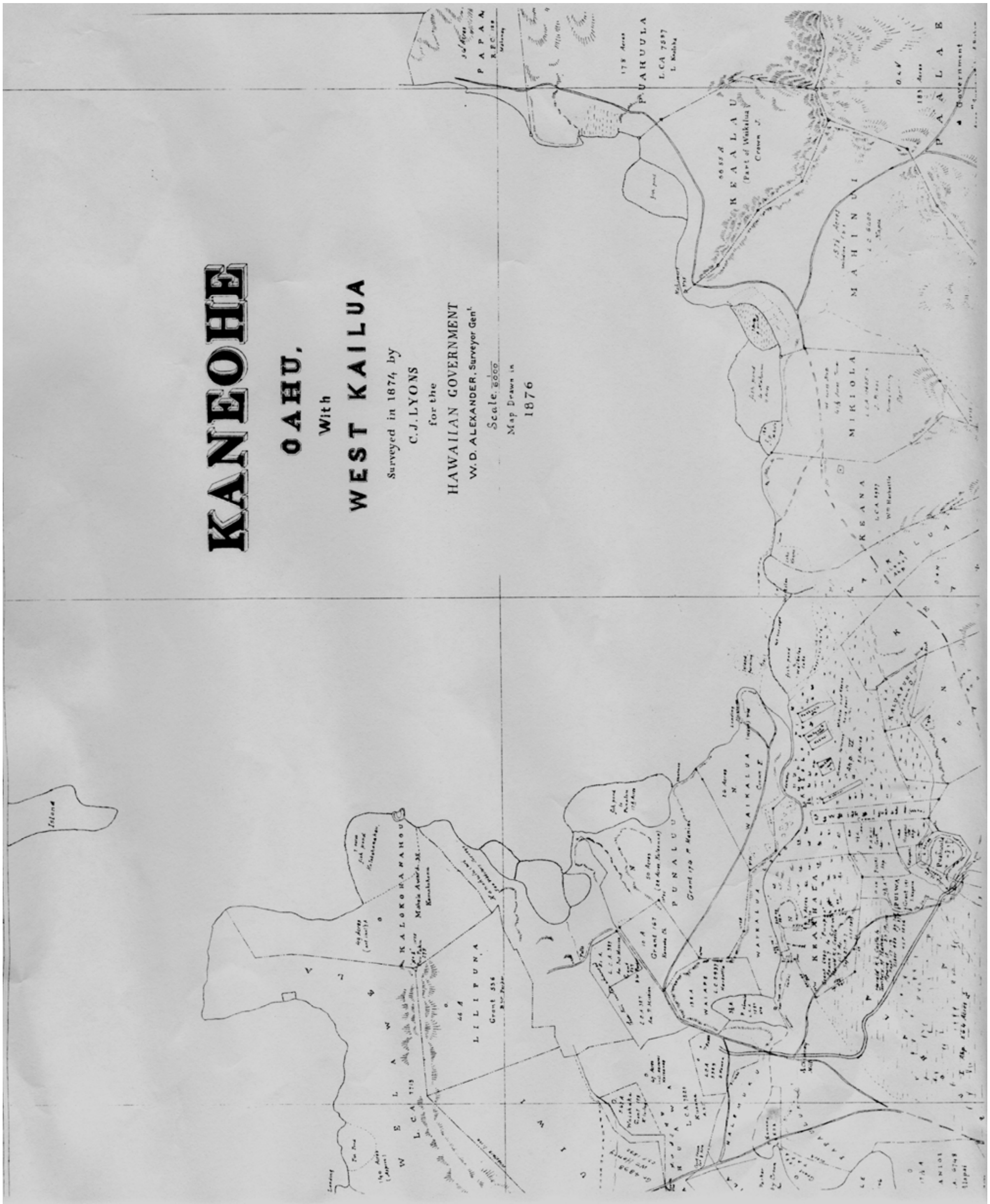

Figure 4. Portion of 1876 Map of C.J. Lyons 1874 Survey with Fishponds and Named *`ili*
(from Devaney et al. 1976: Fig. 139)

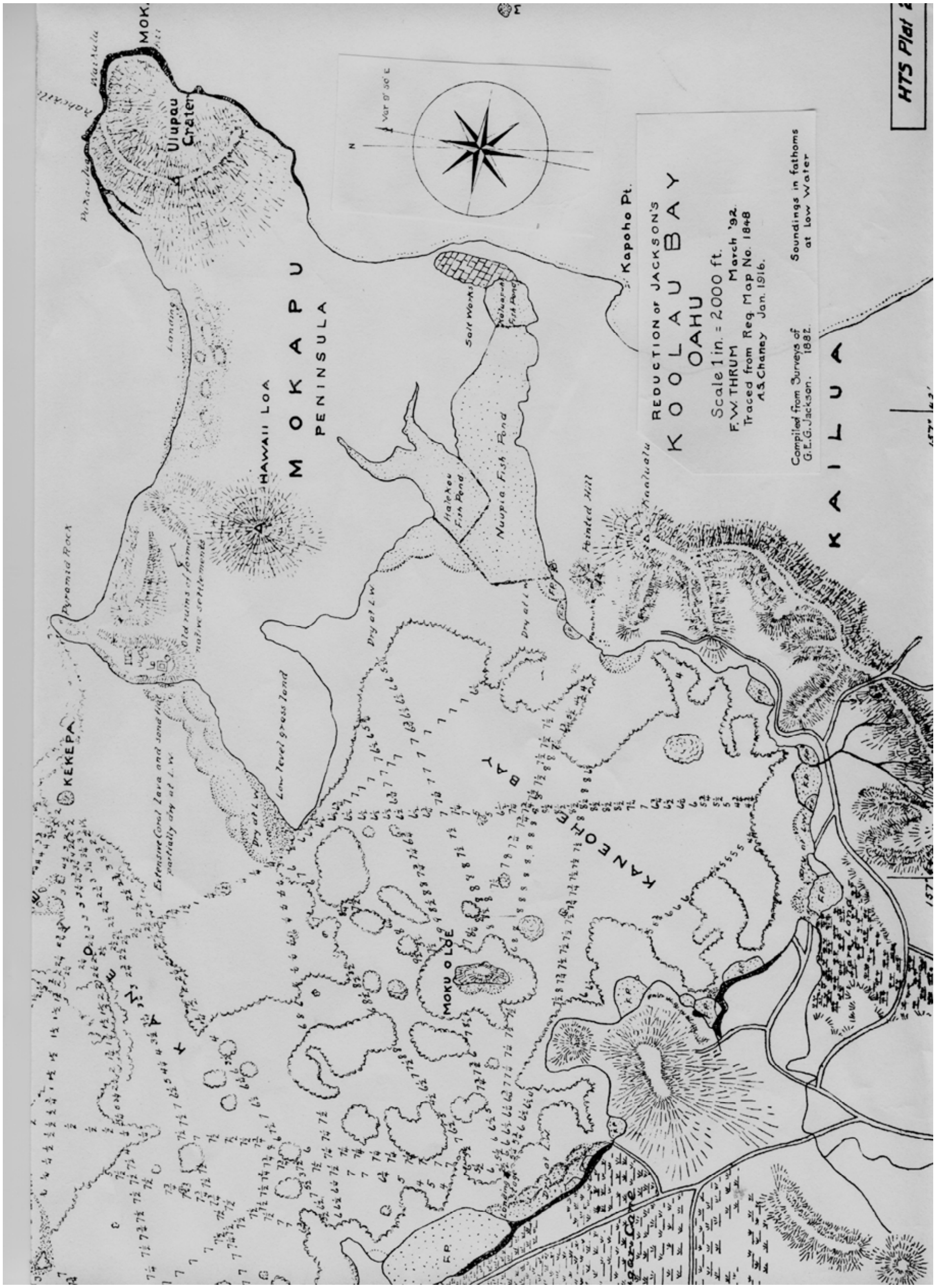

Figure 5. Portion of 1916 Registered Map No. 1848 Based on G.E.G Jackson Survey of 1882
Note Fishponds, Kekepa Islet and Moku-o-Loe (from Devaney et al. 1976:Fig. 140)

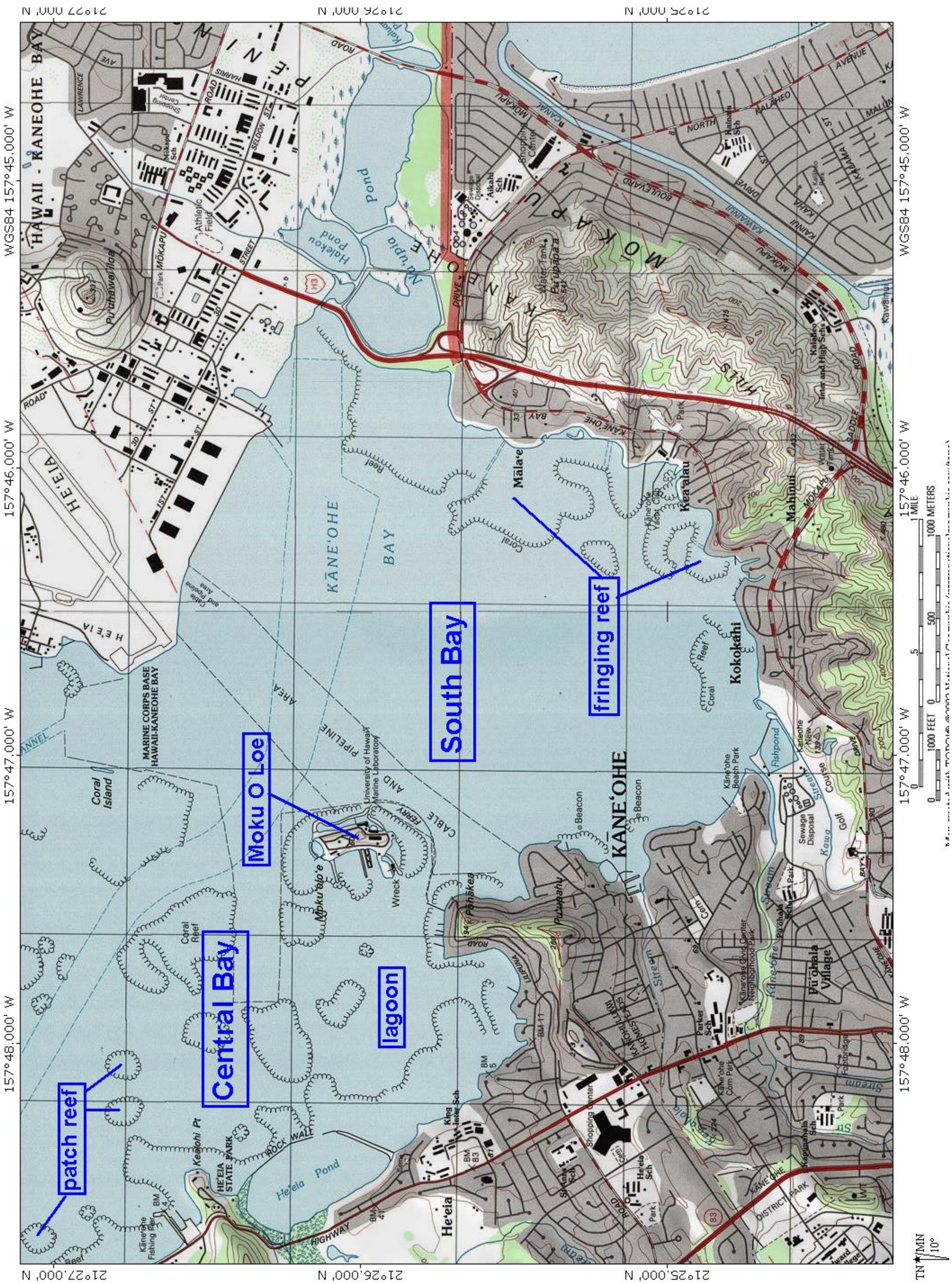

Figure 6. Kane`ohe Bay: South and Central Bays with Reef Types

Consequently, the southern part of the bay has been subject to more adverse impacts from development-related siltation, expansive dredging activities, and intentional sewage outfall during the latter century as well as periodic spills during heavy rainfall conditions that exceed the storage capacities of the waste water facilities that occupy the area surrounding the bay.

The shoreline bordering Kane`ohe Bay incorporates nine *ahupua`a*; from the north; Kualoa, Hakipu`u, Waikane, Waiahole, Ka`alaea, Waihe`e, Kahalu`u, He`eia, and Kane`ohe (Fig. 7).

The current study is concerned with the cultural background and use of the southern part of Kane`ohe Bay, located within Kane`ohe *ahupua`a*.

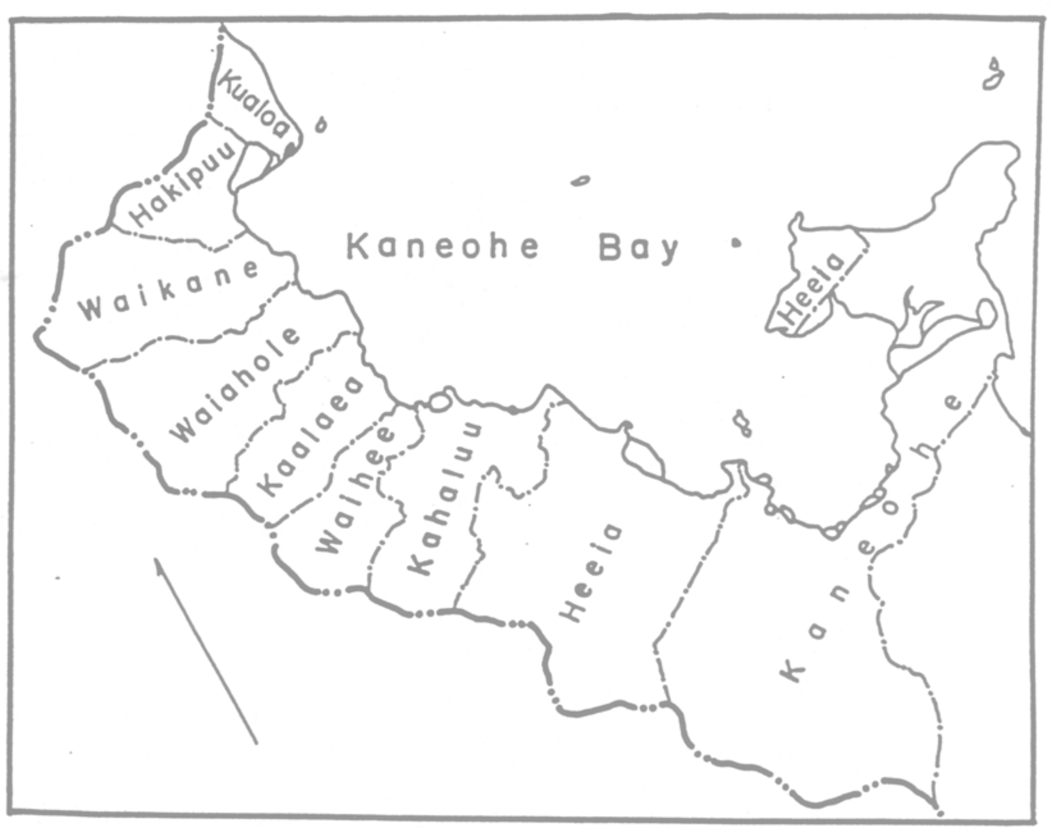

Figure 7. The Nine *ahupua`a* Bordering Kane`ohe Bay
(from Devaney et al. 1976: 6 Fig. 1)

TRADITIONAL OR LEGENDARY BACKGROUND

The earliest accounts of the lands of Ko`olaupoko appear in legends about Hawaiian gods and demi-gods. Hiiaka, Pele's younger sister; Hina, who left earth to dwell on the moon; and Kane, one of the four principal Hawaiian gods are all associated with the district (Pukui 1926). Kane was the Hawaiian god of creation and ancestor to both chiefs and commoners (Westervelt 1907:82 in Devaney et al.1976:1). The land of Waikane bears his name because he first dug for water there (Pukui 1926). However, his name does not appear to be associated with the name of the subject *ahupua`a.* The name, Kane`ohe, literally means "bamboo husband." According to an oral tradition, a woman when asked about her husband by another compared his cruelty to the cutting edge of a bamboo knife (Pukui et al. 1974:85; Sterling and Summers 1978:205).

For the prehistoric Hawaiian people, the gods were not only relegated to legends and oral traditions, but were incorporated into various aspects of their daily life. Prayers or *oli* (chants) were offered prior to each new event to smooth the way and ensure success for a new undertaking and to give thanks for divine aid upon the successful completion of an event. The *kapu* of the gods pertinent for each activity, ie. fishing, planting, and gathering, were applied with appropriate behavior to suit the requirements of the occasion. The essence of such customs or protocols can be interpreted as ways in which the Hawaiian people sensitized themselves to their environment (Devaney et al. 1976:1-2).

For the early Polynesian arrivals with a horticultural and marine exploitation subsistence base, windward O`ahu, particularly Ko`olaupoko, was an ideal location for the establishment of permanent settlements (Fig. 8). The marine environment of Kane`ohe Bay with barrier reef and lagoon, perhaps reminded these early settlers of their home islands, prompting them to settle in this region.

The windward region of Ko`olaupoko has long been considered the "bread basket" of O`ahu and highly favored with well-watered agricultural lands and verdant fishing grounds. Many prehistoric personages are said to have resided there including La`amaikahiki who upon voyaging from Tahiti landed and resided in a place formerly known as Wai-hau-palua, which over time came to be known as Waikalua (Sterling and Summers 1978:209). The following account is found in *Sites of O`ahu*:

> Site of the houses of La`amaikahiki, Waikalua, Kaneohe. The home of David Trask now occupies the site. This is about 100 feet from the water with an elelvation of some 50 feet above high tide, which is somewhat higher than the land immediately surrounding the place. On the southeast side of the Trask home

> is an oval pile of rocks, 20 feet long, 15 feet wide, and 3 feet high, with a great amount of coral scattered throughout. This was probably connected in some way with the old site, for the stones are said to have been undisturbed. A similar pile of coral and stones, though much smaller, is found on the other side of the houses. The sands in front of the place are known as Naonealaa and were tapu to the commoner when the ali`i lived there.
>
> La`a, that is, La`a-mai-Kahiki was so named for his coming from Kahiki. After the death of Olopana. the kingdom was inherited by La`a, and he heard from Kila and others that Hawaii was a fertile land, and that the people were great farmers and keepers of fish in fish ponds. Oahu was the richest of all so La`a became determined to come here to Hawaii.
>
> …There was a man at Hanauma named Ha`ikamalama. When he heard the sounds from the sea he wondered what it was. It was the sound of the big and little drum, therefore he thumped the rythmn on his chest with the tips of his fingers…The sound seemed to come from the sea on the Koolau side, so he sailed to Makapu`u. He saw them going by on the ocean so he went by land until he saw the canoe heading toward Ka-waha-o-ka-Mano. He guessed that they were going to Kaneohe in Koolaupoko. When the canoe reached Wai-hau-palua, he ran to the shore with his fingers beating the rythmn and he chanting the chant to Kupa.
>
> When La`a and the men on the canoe noticed this, they were astonished. He knew their names through their playing of the kaeke. La `a threw out some sand as a resting place for the canoes. This place is now called No-one-a-La`a (La`a's sands). It is in Kaneohe. (Sterling and Summers 1978:209-210)

Another account from the same source describes Ka-Pa-Puaa, or pig pen, at Waikalua:

> Over against this alter beside the chiming waters of Hiilaniwai on Mountain bright (Keahiakahoe), down by the sea, stood the pagan outfit of a dark sorcerer who plied his damnedest black arts for a fee. His establishment was near a fenced area of about thirty acres of wild rocky land called the "Waters of Slaughter" or Waters of Depression. "Wai-ka-lua." Here the old fellow did his wizardry and was supposed to counsel with evil spirits in the still dark night…..
>
> Nearby this wizard's hut, according to old timers, were two springs whose waters possessed supernatural power. Out of one, they said, come healing streams that imparted life and purity of soul to all who drank of it. The other poured forth a stream that carried spirits of demonical possession concealed in its waters, and spread eternal chaos and cruel death on every form of life it touched.
>
> As the story goes: Once the gods of the netherworld and the spirits of the world engaged in furious battle over these springs. The Lights won and drove the subterraneous to an adjacent area or field at Waikalua. Here the defeated gods wreaked their rage for their defeat on every animate creature within reach, until, following another encounter with the gods of the upper world, they were driven to a place called "Milu" in the center of the earth. Later the scene of the battle was fenced off from the surrounding holdings and named "The Pig Pen"—"Ka-Pa-Puaa." (Sterling and Summers 1978:209)

Other oral traditions of poisoned wells and sorcerers are known for the Keana locality of Waikalua as well. These may be variations of the Ka-Pa-Puaa account.

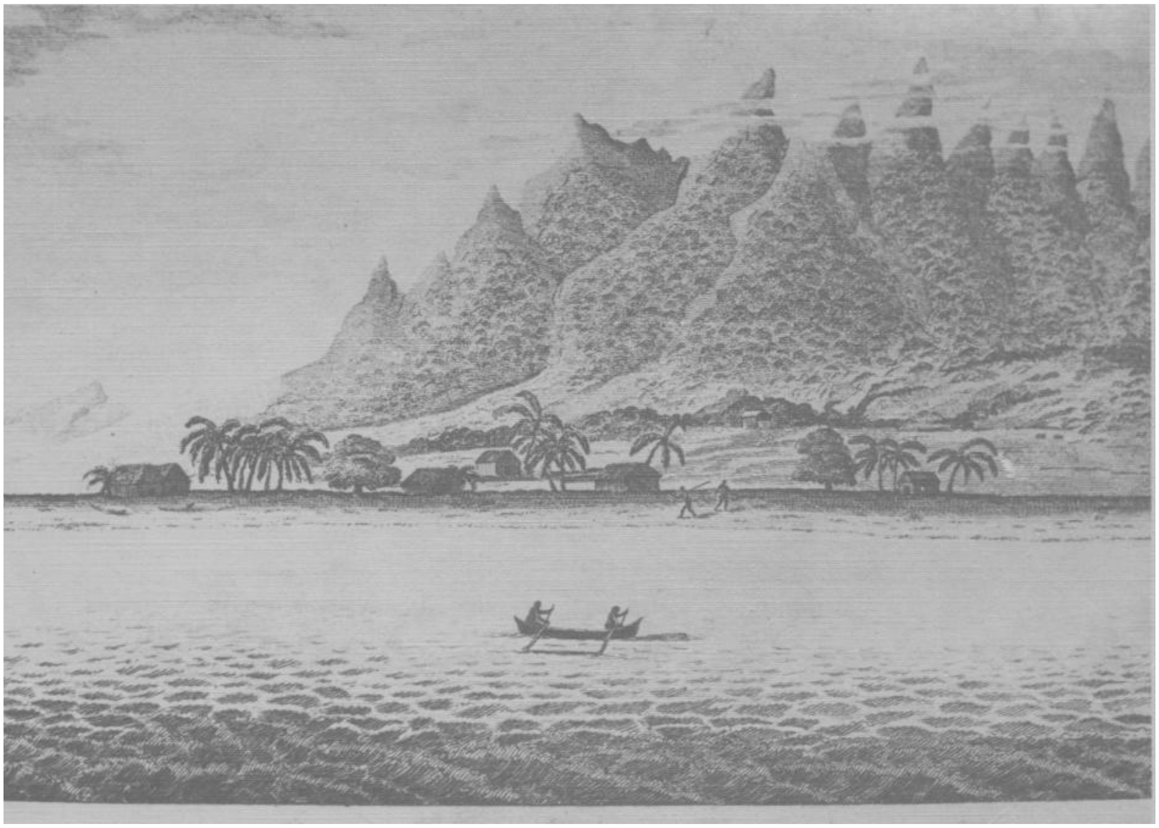

Figure 8. “A View in the Bay at Woahoo, Sandwich Islands” (Portlock 1789); Kualoa in 1786 (from Devaney et al. 1976:cover illustration)

Based on the oral traditions and legendary accounts, the Kane`ohe Bay region appears to have been favored as a rich and productive agricultural as well as marine resources area during the prehistoric period. Thus, dry land cultivation of such crops as sweet potato, yams, and breadfruit; wetland cultivation of taro; and aquaculture in the coastal fishponds and in the estuarine areas were practiced along with fishing in the near shore, lagoon, and deep ocean zones. These activities were supplemented by gathering for other land as well as marine resources and limited aquaculture in the *lo`i* or pond-fields.

EARLY HISTORICAL BACKGROUND

During the early historic times, many of the ruling chiefs favored Kane`ohe as their place of residence. Kahahana the ruler of O`ahu sometimes resided there. Kahekili after defeating Kahahana lived in Kailua, Kane`ohe, and He`eia. In 1795, Kamehameha I when apportioning the conquered O`ahu lands to his high ranking supporters, he retained Kane`ohe *ahupua`a* for himself. Later his sons inherited much of Kane`ohe, Kahalu`u, and Kualoa. During the Mahele, Queen Kalama, the wife of Kamehameha III was awarded 9,500 acres of Kane`ohe *ahupua`a* as well as large land tracts in Kailua, including LCA 4452 which incorporated the Aikahi area. Over 40 Land Commission Awards occurred in the vicinity of the Waikalua end of the project area, with the majority described as agricultural lots, either *lo`i kalo; mo`o aina,* narrow strips of land; or *kula* for dryland agriculture. Two types of Land Commission Awards took place during the mid-1800s. The first was the apportioning of lands to chiefs and konohiki which consisted mostly of large acreages or multiple parcels. Later the *kuleana,* or the native tenant parcels, usually no larger than 10 acres, were awarded. The Waikalua land segment of the Kane`ohe Kailua Force Main No. 2 Project and adjoining areas include many such awards of both types (Fig. 9). All of the parcels traversed by the project alignment were described with agricultural land use. The distribution of these *kuleana* parcels are considered to be the continuation of traditional land use patterns, thus good indicators of traditional cultural activities.

Traditionally, *ahupua`a* boundaries extended into the sea adjoining the *ahupua`a* and its resources were shared by the chief and all the tenants living in the particular *ahupua`a*. During the period when some of the traditional customs regarding lands were being given legal status, this concept of undivided shares still seems to have been continued as the underlying basis for the newly adopted laws. However, just as the Great Mahele introduced private ownership of lands, the undivided shares gradually turned into privately-owned shares in the fisheries as well. All fisheries beyond the barrier reef were common property to all people. The area inside the barrier reef to the shore was assigned as part of the adjacent *ahupua`a* (Fig. 10), fishing rights belonging to both the chiefs and tenants (Devaney et al. 1976:135). Fortunately, such laws grew complex over time, but the rights of the commoners were always acknowledged and in June of 1900, the Organic Act repealed all laws "which conferred exclusive fishing rights upon any person…" (Devaney et al. 1976:136). Fishponds however, were excluded from these laws. Jackson's marine survey of 1882 recorded a total of 25 coastal fishponds although a compilation of other sources indicate a total of 30 fishponds along the Kane`ohe Bay shoreline during this period.

Although many species of fish and other ocean resources were available in the south bay, perhaps the most significant may have been the *nehu* or baitfish. In earlier times, it was said that *nehu* were considered a source of food in Waikalua, Kane`ohe (Devaney 1976:125). With the advent of commercial tuna fishing in early 1900s, there was a high demand for *nehu* as bait fish and nearly 60% of the total commercial baitfish catch between 1948 and 1960 came from Kane`ohe. An intensive study of *nehu* in the bay in 1948, showed that *nehu* eggs were most abundant in the

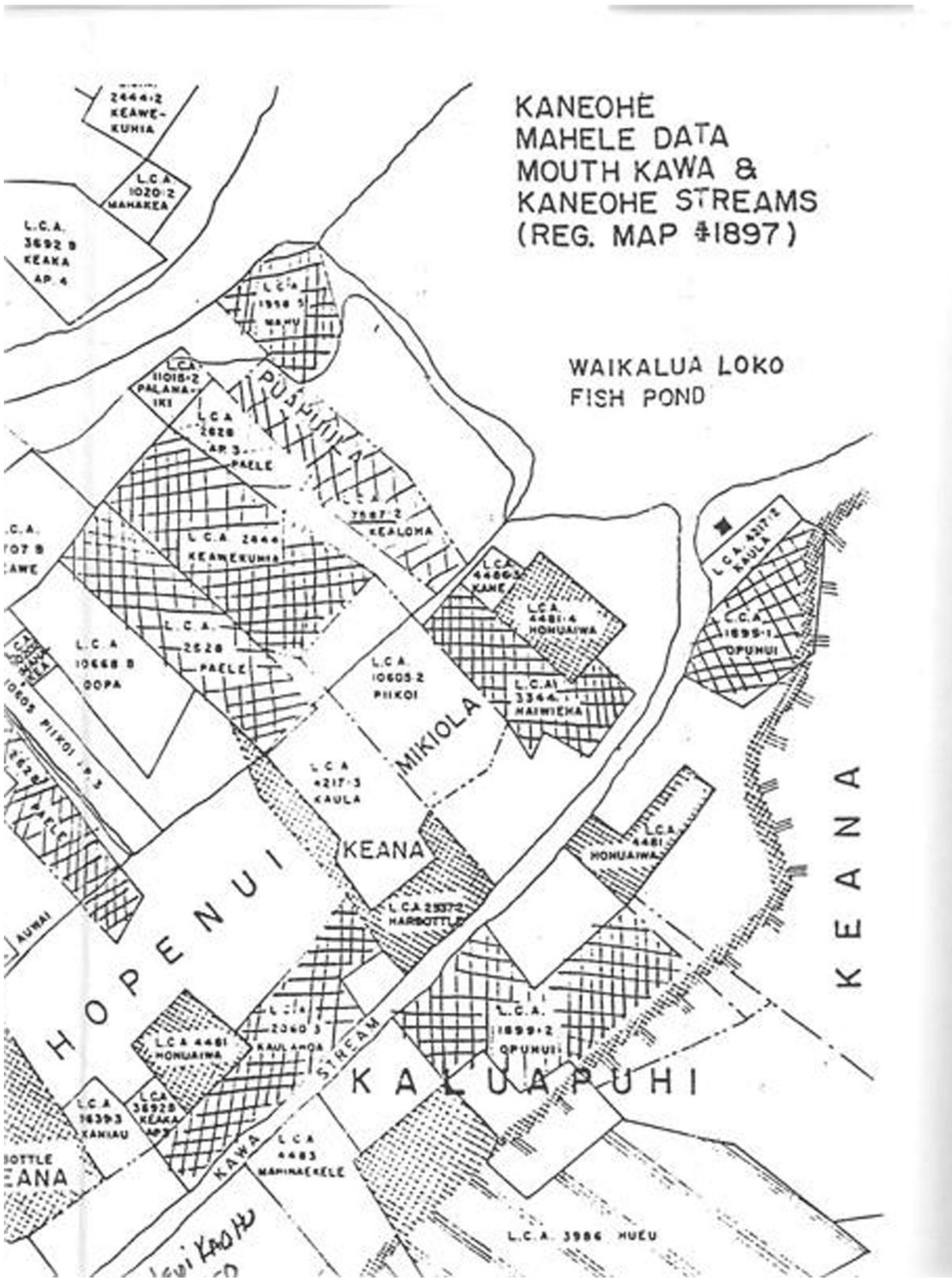

Figure 9. Portion of Map Compiled by Cordy (1977) Showing LCA in Waikalua
Piikoi and Harbottle are examples of *ali` i / konohiki* Awards
while Honuaiwa and Kane represent *kuleana* Awards
Note the three `ili names in large type (from Hammatt and Borthwick 1989:21)

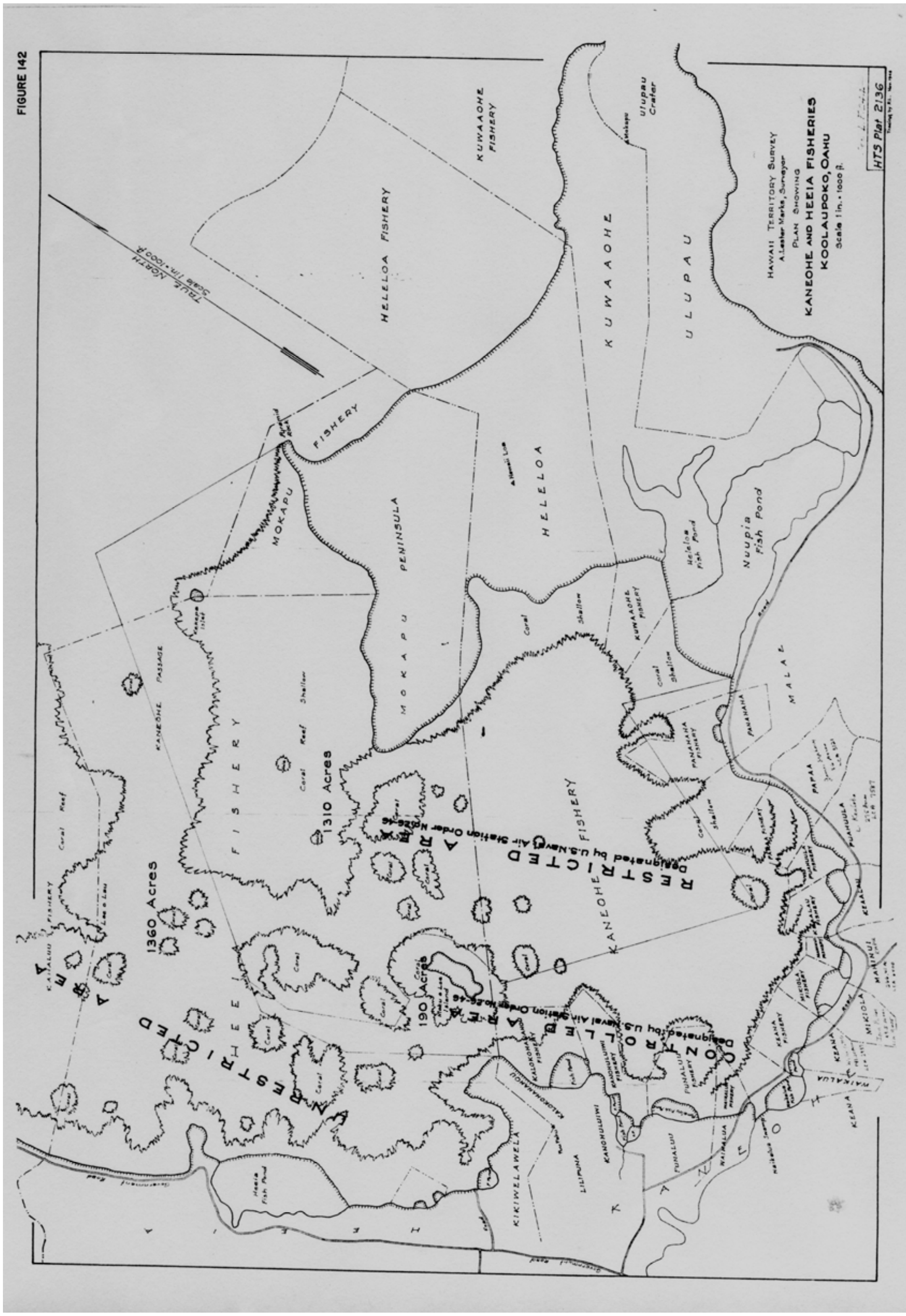

Figure 10. Map Showing the Various Fisheries within the South Bay
(from Devaney et al. 1976: Fig. 142)

south bay (Devaney et al. 1976 :127-128). Available commercial catch statistics between the mid-1940s and early 1960s show a general decline in the total catch for most fish. The increases seen may also be attributable to the increase of commercial fishing and techniques used, although marine scientists also noted the influence of “environmental factors.” (Devaney et al. 1976:127-129).

Thus, the early historic period was generally a continuation of the traditional subsistence lifeways with farming and fishing as the main occupation. The Kane`ohe Bay region was still regarded as a rich and productive resource area and favored by high ranking chiefs and royalty.

LATE 1800s TO EARLY 1900s

Although the construction of the Hawaiian coastal fishponds likely caused some limited impacts to the shoreline and other parts of Kane`ohe Bay representing the commencement of the impact of human activities on the natural environment, the advent of a series of large scale commercial agricultural ventures during the period between the late 1800s to the 1920-30s marked the real beginning of extensive adverse impacts upon the waters and biota of Kane`ohe Bay. The effects of such activities directly and indirectly affected the long practiced activities of marine resource exploitation in the bay as well as traditional farming in the surrounding *ahupua`a*.

The earliest of the large commercial agricultural ventures started with the cultivation of sugar cane in Kualoa in the 1860s. By 1880, three more sugar companies had emerged in Kahalu`u, He`eia, and Kane`ohe. In 1880, the plantation in Kaneohe reported 7,000 acres available for cultivation. The commercial cultivation of sugar cane was short-lived because it was never as successful as in other parts of the island due to the limited availability of arable level lands. By 1885, seven plantations had ceased operations with one lasting till 1903. However, in the 25 years, the large scale clearing of land not only impacted inland and coastal dry land farming areas, but also the soil runoff from the expansive cleared areas caused siltation in Kane`ohe Bay. The south bay was especially susceptible since the sea water circulation was more restricted than in the other parts of the bay.

The commercial cultivation of rice did not occur in earnest until the decline of sugar, and in 1880 the first Chinese rice company started in the Waihe`e area. Abandoned systems of *lo`i kalo* were modified into rice paddies. The Kane`ohe Rice Mill was built around 1892-1893 in the Waikalua area (Devaney et al. 1976:49-51). Another commercial crop, pineapple, was also grown in the Ko`olaupoko region starting around 1910 and continuing on until the mid 1920s. Portions of Ko`okaupoko, especially Kane`ohe was also used for cattle grazing and ranching starting in the mid-1840s. Kane`ohe Ranch at one time operated 12,000 acres of ranch land with 2000 head of cattle. Ranching continued into the early 1970s. All of Mokapu Peninsula, now occupied by the Kane`ohe Marine Corp Base Hawaii, was at one time a grazing area (Devaney et al. 1976:70-74).

The compounded effects of these large scale commercial ventures had deleterious effects upon the land, the ocean, and the general environment of the Kane`ohe Bay region. The commercial agricultural endeavors altered expansive land areas contributing to the silting in of Kane`ohe Bay as well as diverting the natural freshwater sources. The ranching activities cleared cover vegetation from many areas and denuded the lands thereby adding to the erosion and siltation of Kane`ohe Bay.

PRE-WWII TO THE 1970s

The most destructive impacts to Kane`ohe Bay occurred during the period prior to, during, and following WWII. The direct impacts of dredging within the bay both before and during WWII and the indirect effects of rapid population increase in the region following the end of the war, contributed to the most expansive adverse impacts to the marine and terrestrial environments in the region surrounding Kane`ohe Bay.

The beginning of the most drastic changes to the bay came in 1915 with the first dredging permit issued for the bay by the Army Corps of Engineers. Most of the early permits were for boat landings, piers, and wharves (Fig. 11). Included in these are the 1,200 ft. wharf at Kokokahi in 1928 and the 50 ft wharf on Moku o Lo`e in 1934 (Fig. 12). But the most extensive dredging came with the takeover of Mokapu Peninsula by the U.S. military in 1937. Comparing Jackson's soundings in 1882 with those recorded by the US Coast Guard in 1927 produced no significant changes in depth. But the 1927 results compared to a study done in 1969 by Kenneth Roy show an average decrease in depth by 5.4 ft. Analyses of the fill material also found that 3.9 ft of the sediment was reef derived and 1.5 ft. was land derived. The notion was since all of the dredged material was used as landfill the increase was the result of "increased runoff and increased suspended load brought to the bay by streams." However, dredging reports from 1939, 1942 and 1944 showed that not all of the excavated material was used for landfill in the construction of the Naval Air Station on Mokapu Peninsula.

Even before 1940 it was recorded that not all of the dredged borrow was used in the construction of the Naval Air Station:

> "All of the dredging, [209,065 cubic yards from take off area and 30-foot channel] were pumped overboard, that is back into the water areas adjacent to the

Figure 10. Aerial Photo from 1928 Showing Piers, Wharves, and Docks in the Waikalua Area
(Aerial Photograph from Bishop Museum Library, Visual Archives)

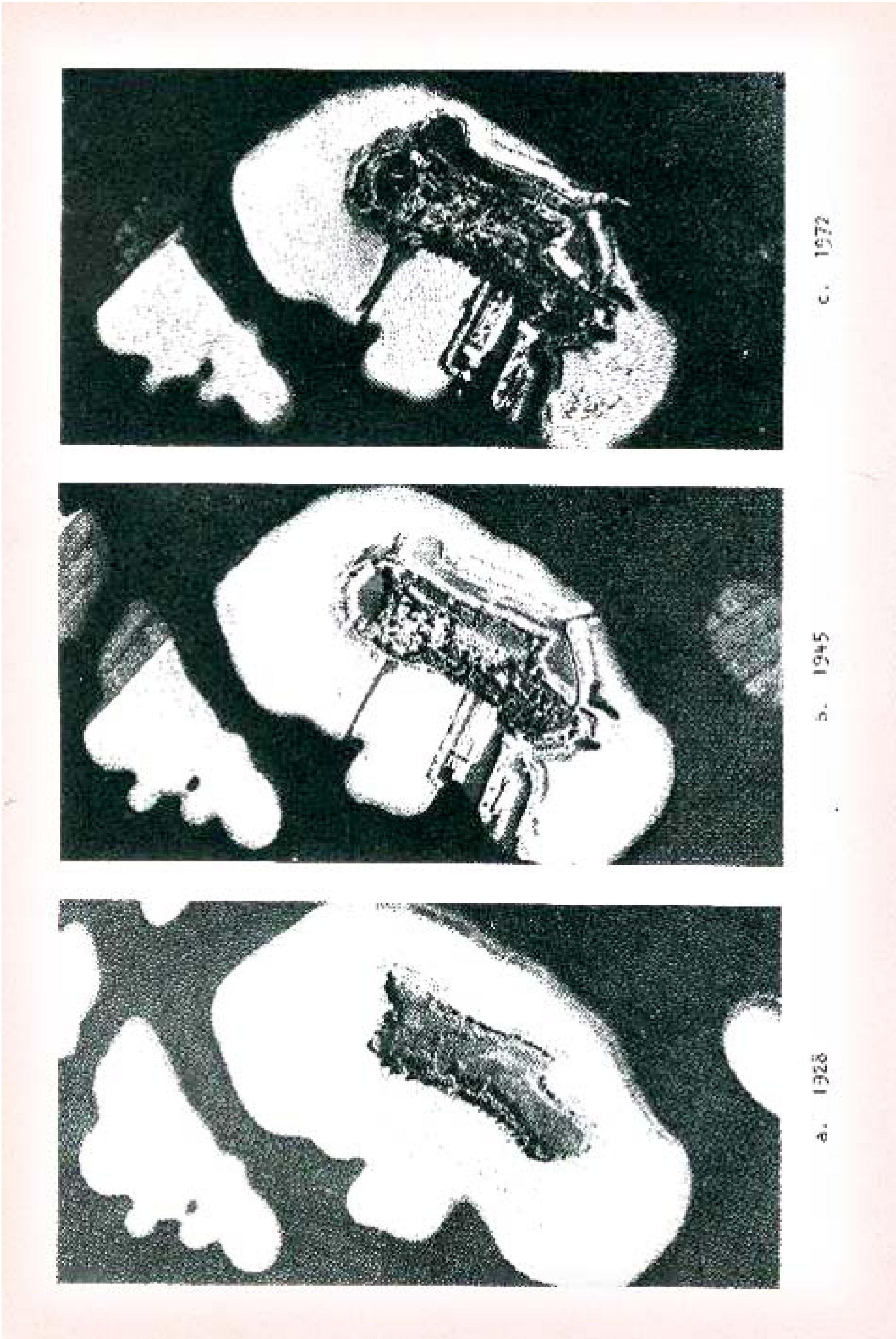

Figure 11. Progression of Dredging and Construction at Moku-o-Loe Between 1928 and 1972
(from Devaney et al. 1976: 196)

> dredge …The end of this line was moved periodically so that material did not build up above the minimum depth of 30 feet." (Devaney 1976: 117)

The method of infilling of the south sector of the bay was sometimes described in the reports as in this 1944 report:

> "The material from this area [east of Kalokohanahou], which was dredged to eleven feet, was pumped into deep water disposal areas on either side… A spreader barge used in order that the fill should not exceed the limits of the required ten-foot depth." (Devaney 1976:117)

In January of 1942 it was reported that the dredge had been dumping inside the bay all that month east of Area H. Area H was off of Kahalu`u *ahupua`a* outside of Kahalu`u Fishpond (Devaney et al. 1976:117). The dredged spoils apparently were dumped throughout the interior of the bay.

The most apparent direct adverse impacts of these dredging activities were the in-filling of coastal fishponds. During 1946 to 1948, nine fishponds encompassing a total area of almost 60-acres wee filled. Eight of these were located in Kane`ohe *ahupua`a*. By 1976, there were only 12-walled coastal fishponds remaining in Kane`ohe Bay with some of these only partially intact (Devaney et al. 1976:118).

In the period following WWII, windward O`ahu, particularly Ko`olaupoko experienced a tremendous increase in population, especially after the Pali Tunnels were opened in 1957 followed by the Wilson Tunnel in 1960. Between 1960 and 1970, the windward side underwent its highest recorded rate of population increase, undoubtedly linked to the completion of the two tunnels (Devaney et al. 1976:172).

By the late eighteenth and early nineteenth centuries a population range between 14,600 and 18,400 persons for the nine *ahupua`a* with frontage on Kane`ohe Bay could be estimated (Devaney et al. 1976:7). Foreign borne pestilence and also the movement of people to the developing urban centers in and around Honolulu in leeward O`ahu had depopulated the Kane`ohe Bay area so that by 1831-1832 the population had decreased to 3,019 persons. Kane'ohe *ahupua`a* had the most persons at 1,159 which was twice as many as the next highest number in neighboring He`eia (Devaney et al. 1976:8-9). The population continued to decline to its lowest point in 1872 with 2,082 for all of Ko`olaupoko. By 1896, however, it had increased to a total of 2,753 persons which was the result of imported labor, most likely Chinese who were cultivating rice and operating the fishponds in Kane`ohe Bay (Devaney et al. 1976:11). Following WWII, Kane`ohe became a popular residential area based on its proximity to downtown Honolulu, especially following the completion of the Pali and Wilson Tunnels in 1957 and 1960 repectively. Between 1940 and 1960 the population of Kane`ohe more than quadrupled from 5,387 to 29,622 and by 1980 had reached 47,335 (Devaney et al. 1976:13 and Kane`ohe Bay Master Plan 1992:5).

The bay has been impacted by the various effects of rapid urbanization in the period following WWII, including extensive shoreline modifications, increased runoff, and sewage outfalls, both intentional and accidental. Until 1977-78, raw or minimally treated sewage was being discharged into the south bay. A brief chronology of sewage disposal follows:

1940s – The Marine Base on Mokapu Peninsula was the first to release untreated primary sewage into the south bay;

1963 - The Kane`ohe Sewage Treatment Plant in Waikalua becomes operational, discharging secondary treated sewage into the south bay in a depth of 8 meters; prior to that, all municipal sewage was handled by a network of cess-pools and septic tanks and discharged into a stream;

1970 - A small secondary treatment plant developed in conjunction with residential development in Ahuimanu became operational and began discharging secondary sewage into the north bay;

1975 – The total volume of sewage discharged from the preceding three sources totaled 17,000 cubic meters per day, with 70% coming from Waikalua in the south bay; and

1978 - A new deep water outfall into 30 meter depth outside of Mokapu Peninsula was completed, and all sewage was permanently diverted to the Mokapu outfall, and this has been followed by various additional improvements (Coles et al. 2002: 18-19).

However, the compounded effects of nearly 40 years of intentional sewage discharge into the south bay together with the periodic spills that occur due to heavy rain conditions have severely impacted the viability of the natural biota of the bay which were already impacted by siltation and dredging that were concurrently taking place.

A 1970 study undertaken in Kane`ohe Bay by the University of Hawai`i concluded that "the reefs of the southern sector of the Bay are virtually devoid of living coral; the reefs of the middle sector have the once dominant coral being invaded, killed, and decalcified by the alga Dictyosphaeria cavermosa; only the reefs of the northern sector and outer waters of the Bay seemingly are still unaffected" (Banner and Bailey 1970:1). It was further suggested that the urbanization of Kane`ohe was the cause of the eutrophication of the Bay. The over abundance of certain species and the death of others found in the bay coincided with the rising population on the southern shores of the bay, untreated sewage being discharged into the bay, and increased siltation.

In the 1930s, some attempts at aquatic species introduction into parts of the south bay, mostly within the fishponds, proved successful, with the Japanese clam, Japanese little-neck clam, and Japanese oyster propagating well in the ideal conditions within the bay. However, the dredging activities soon after the start of these experimental introductions brought a rapid demise to these operations. Clamming continued to be a popular, non-commercial seasonal activity, especially in the Nu`upia Pond area of Mokapu. However, a ban was effected in 1969 after soil erosion following unusually heavy rains caused a massive die-off of the clams. The ban is still in effect today (Devaney et al. 1946: 101).

Of all of the commercial activities started during the preceding historic period, only two persisted into the modern era in the subject region with only one still continuing today. These were the commercial fishponds and cultivation of taro. One of two recorded fishpond operations ended in the late 1960s after the Keapuka floods breached the walls of Waikalua-loko Fishpond, the other at Moli`i Pond in Hakipu`u closed in 1999 when the caretaker retired. A short-lived revival of commercial oyster farming was attempted at Waikalua-loko in the early 1970s in tanks using water from this pond, but this venture could not produce viable results. By 1976, only one fishpond, Moli`i, in Hakipu`u *ahupua`a* was still being commercially operated (Devaney et al. 1976:145). At the end of 1944, about 544 acres of land in Ko`olaupoko District were still being cultivated for taro and in 1970, at least half of the taro production on O`ahu was still being produced in the Kane`ohe region (Devany et al. 1976:37-38). Taro farming today is still practiced in inland portions of the *ahupua`a* valleys surrounding Kane`ohe Bay.

That this most recent historic period had the biggest adverse impact on the bay as well as the long standing traditional cultural practices is apparent from all of the foregoing information. That the rapid urbanization of windward O`ahu and the accelerated expansion of the resident population over-stress the existing, aging infrastructure such as roads, sewage treatment and transmission systems is obvious.

RESULTS OF RECENT CULTURAL STUDIES REVIEW

Searches for cultural impact studies for the subject region completed roughly within the past two decades were conducted in the Pacific Collection at the Hamilton Library, University of Hawaii at Manoa; the Hawaii State Library; the State Historic Preservation Division Library in Kapolei; the Bishop Museum Library and Archives; and the online EA/EIS archives maintained by the Office of Environmental Quality Control.

Six environmental documents, potentially pertinent to the current project area, were reviewed, but no cultural studies were found to have been undertaken in conjunction with these studies. The six studies were:

1. 1984 EIS for Kane'ohe-Kailua WWFacilities: Kane'ohe STP is within a SMA, Kailua STP is adjacent to an SMA; Maunawili, Kukanono, and Pohakupu STPs are all within SMAs. No environmentally significant lands are w/in the project area. Ulu Po heiau is near Pohakupu STP but no other historic/archaeological sites are located within this project's boundaries (p. 3-17). Kane'ohe STP is in a flood-prone area at the mouth of Kawa Stream.

2. 1993 EA for Kane'ohe WW Pump St. 5: Declaration of No Adverse Effect. Reclaimed land with no historic or archaeological sites (p. 21).

3. 1998 EA for Kane'ohe WWPS Modifications, PH. IIIA: No potential effect.

4. 2000 EIS for Kane'ohe-Kailua-Kahalu'u Facilities Plan: No indirect or direct impacts anticipated.

5. 2000 EA for K-Bay Sewers Improvement: FONSI. According to the report by Cultural Surveys HI, the former Panahaha Fishpond was potentially still present below the fill layers at the project's north end. The potential for habitation areas or burials was also indicated (p. 32). However, upon excavation, CSH found no evidence of a fishpond nor other remains.

6. 2001 EA for K-Bay Pier: 30 fishponds were identified in the 19th century and from 1946-48 nine were filled. Only 5 remain intact (p. 15). Nu'upia Pond, adjacent to Kailua Regional WWTP is an important habitat for the Hawaiian Stilt. FONSI declared.

Unfortunately, the search of available recent material produced no pertinent cultural study involving the immediate current study area, the southern sector of Kane`ohe Bay. The absence of pertinent cultural studies may be attributable to the following factors:

1. The fairly recent application of the Cultural Impact Assessment requirement;

2. The paucity of major undertakings, after the requirement took effect, within or in the vicinity of the current subject region; and

3. The absence of a formal reviewing entity for such studies which makes for an inconsistent application of the requirement as well as the guidelines.

However, the results of studies undertaken for the adjacent Mokapu Peninsula area were found to be relevant to the Aikahi land segment of the current project area.

In 1995, Paul H. Rosendahl, Inc. (PHRI) conducted a study for the Department of the Navy. The specific tasks of the project were to : (a) conduct both oral history and archival research to assess the eligibility of Pu`u Hawai`i-loa as a Traditional Cultural Property, (b) identify other traditional cultural properties on Mokapu Peninsula, and (c) to show a good faith attempt at determining the nature and antiquity of the Hawai`i-loa tradition.

In this study, 18 people were interviewed and four more informants were quoted from previous studies. Of those interviewed four informants had lived or worked on Mokapu Peninsula. The interviews are summarized on Table 1 from the PHRI report:

Table 1.
Mōkapu Peninsula, Interview and Archival References of Site and Resource Significance

Source	Prominence of Pu'u Hawai'i-loa in the Mōkapu Cultural Landscape and as a Significant Linkage Among View Planes	Lu-o-wai-o-Kanaloa	Hawai'i-loa Spring	Legends of Hawai'i-loa the Navigator	Other Legendary Resources	Hawai'i-loa Heiau	Other Heiau	Deity	Ceremonial & Spiritual Significance	Iwi — Hawaiian Burial Remains	Aloha 'Āina: Love and Respect for the Land	Fishponds & Pā'ōhua	Fishing Practices	Archaeological Resources	Harvesting Resources	Salt Making	Participation in a Community Stewardship Partnership	Familiarity w/ the Name Hawai'i Loa
Anita Gouveia & Toni Auld-Yardley	X		X	X		X		X	X	X	X	X	X	X	X	X	X	X
George & Mary Davis	X	X			X		X	X	X	X	X	X	X	X	X	X	X	
Henry and ColleenWong		X					X			X	X	X	X	X		X		X
Jack & Georgiana Williams	X						X	X	X		X	X	X	X	X		X	
Edith Auld	X	X					X	X	X	X	X	X		X	X		X	
Lucia Whitmarsh							X	X	X		X		X	X	X	X	X	
Agnes McCabe-Hipa									X		X	X	X	X	X		X	
Joseph Haia	X	X					X	X	X	X	X	X	X	X	X	X	X	
Aaron Chaney					X		X		X	X	X	X	X	X			X	
Margaret Date							X			X	X	X	X	X		X		
Jeri Kekua-Doo	X									X	X	X	X	X	X	X	X	
Noenoe Zuttermeister-Lewis, Carl H. Zuttermeister, & Freddy Kalani	X		X			X		X	X	X	X	X	X	X	X	X	X	
Carol Kapuaika'iu Shimada							X		X	X	X	X	X	X				
Shizue Okihiro										X		X	X					
Mitsuo Uchibori										X		X	X					
Helen Wahineokai					X					X	X							
Archival Resources	X	X		X	X		X	X	X	X		X	X	X	X	X		X

Note: The "Xs" on this table indicate only that the noted items/places were mentioned during the interview.

As shown on the table, many of the informants had knowledge of and practiced salt gathering and fishing during the time that they were living there. Regarding place names, only two informants were knowledgeable about the name Hawai`i-loa and that was from reading Kamakau's writings and other archival references. All but two witnessed the skeletal remains that eroded from Heleloa beach. Some had come across them while living there and told how their parents or grandparents re-buried them where they were found. Eleven of the 22 informants were familiar with a heiau on Pu`u Hawai`i-loa. Nine of them did not know of the heiau. Again, the two that knew of the name, that knowledge did not come from genealogical or traditional sources but from archival references. However, others that knew of the heiau were told of its existence by the older generation. They were told to "stay away from that place." As a result, few had seen it and those that did, did not recognize what they saw. Those that had visited the site only remember rocks and some walls made out of rocks.

Most of those interviewed did not have previous knowledge of the Hawaiian place names. For instance, no one remembered the name Ku`au, the northwest tip of the peninsula was called Pyramid Rock by those that lived there. It is still called that today. But several remembered Ulupau before the name was changed to Fort Hase. They all remembered the fishponds but most did not know the names of the fishponds or how many there were, except for those that worked the ponds. But activities associated with the ocean resources such as fishing and salt gathering were well known by all. Most of those that lived there full time gathered salt from the area of the salt pans on the Kailua side of the peninsula. Those that did not fish or farm bought or bartered with those community members that did. Most of the people had jobs and many only spent time there on the weekends. Fishing seems to have been a major activity. The fish caught from the ocean was for consumption but the fish from the fishponds were primarily for the market.

Few other cultural resources on Mokapu were related to the interviewers. There were four stones that were on Hawai`i-loa; Kane, Kanaloa, Hina and Ku stones. Of those stones only the Hina stone was still identified in a previous survey by McAllister in 1933. Most of the interviewees had not heard of them. No one remembered Hawaiian religious rites practiced by those living in the 1920's or 1930's associated with Hawai`i-loa. One site that was remembered by two of those that were interviewed concerned the well called Luo wai o Kanaloa. It has since been destroyed and the remains are now under the runway.

The conclusion of the survey indicated the absence of significant new information regarding the nature and antiquity of the Hawai`i-loa tradition. In 1969, Dorothy Barrere concurred with Kenneth Emory, who postulated in 1959 that the tradition of Hawai`i-loa was not an authentic Hawaiian tradition. Their conclusions were based on the following points:

1. No written documentary information was identified.
2. There is a general lack of knowledge of the Hawai`i-loa tradition among the oral historical study informants. The exception to this was only the few who had read or were aware of the 19th century written accounts; and

3. All who read of the information referenced Fornander as the source of the information. But Barrere had discredited the accuracy or authenticity of Fornander's information.

However, in regards to the cultural significance of Hawai`i-loa or the eligibility of the property for the National Register as a Traditional Cultural Place, the study concluded that the nature and antiquity of the Hawai`i-loa legend was not needed. Pu`u Hawai`i-loa was deemed ineligible for determination as a Traditional Cultural Place based on the following:

1. There was no direct association of any tradition of Hawai`i-loa with the hill on Mokapu Peninsula referred to as Pu`u Hawai`i-loa. This information was not borne by any written accounts or by those that were interviewed;
2. there was a general lack of any direct association of the hill itself with the specific name Hawai`i-loa, either by the informants or in the written accounts; and
3. there was no apparent basis for association between the legendary personage Hawai`i-loa and the hill called Pu`u Hawai`i-loa.

Any cultural significance to Mokapu was not due to the name of the hill or the personage named Hawai`i-loa. The heiau on the hill no longer existed. The rock walls that were noted in McAllister's survey could no longer be identified.

Although Pu`u Hawai`i-loa was determined to be ineligible for the National Register as a Traditional Cultural Place, there were ten other sites that were identified from both documentary sources and from the informants. These are listed on Table 2 from the PHRI report shown on the following page. The report stated:

> "A preliminary assessment of these ten sites and areas need to be that while all would appear to have potential, the degree of likelihood that they would qualify as Traditional Cultural Properties varies. All would appear to be tangible properties, though in several instances the actual physical boundaries would have to be defined. Consideration of the integrity of potential properties indicated a need for particularly careful assessment of the integrity of relationship, in order to document associations of demonstrable strength and continuity between individual properties and specific cultural beliefs and practices. Assessment of integrity of condition would also need to be carefully done, as several of the potential properties appear to have been extensively altered from their original condition, and their abilities to convey significance would be questionable. For example, Items 2 and 10 on Table 2, due to lack of integrity, although they still may have archaeological value, may not qualify as Traditional Cultural Properties. Upon initial review, many, if not all, of the potential properties would appear to possibly qualify under one or more of the four basic National Register criteria" (PHRI 1995:72).

Table 2.
Other Potential Traditional Cultural Properties on Mōkapu Peninsula

Name and Type of Site	Reference	Interview No.*
1. Pali-kilo Multiple Reource Complex		
Ancient Village	MacCaughey 1917	6,7,17
Burial	Buck 1964	5,6,7,9
Heiau and Shrines	MacCaughey 1917	5,13
Hina and Ku Stones	MacCaughey 1917	5,6,7,19
Keawanui Heiau	MacCaughey 1917, McAllister 1933	5,6,7,19
Pā'ōhua Fish Trap	Titcomb 1972, McAllister 1933	5
Fish Spotting (kilo i'a) Bluffs	—	7,18
Historic Residences	MacCaughey 1917, McAllister 1933	
2. Lu-o-wai-o-Kanaloa (well and site where offerings were made through the 1930s; now buried under the runway)	McAllister 1933; Sterling and Summers 1988	7,17
3. Mōkapu-He'eia and Heleloa Dunes (Burial Complex, NR Site 50-80-11-1017)	MacCaughey 1917, Mcallister 1933	6,7,9,12
4. Kuwa'a'ohe-Ulupa'u Salt Works	Sterling and Summers 1988	7,17
5. Ulupa'u-Mokumanu (Feeding The Shark God And The Sharks Cave)	Sterling and Summers 1988	6,10
6. Ulupa'u-Kahekili's Leap	MacCaughey 1917,Sterling and Summers1988	—
7. Ki'i Bay and Bluffs (fish spotting)	—	6
8. Pōhakupuka (Kuwa'a'ohe 'Ulupa'u boundary marker)	—	Identified by K. Maly during May 20, 1995 site visit
9. Mōkapu Peninsula Fishpond Complex: (NR Eligible, Site 50-80-11-1002)		
Fishponds	Fornander 1919, McAllister 1933, Sterling and Summers 1988	5,12,14,16,18
Kaluapūhi-Kapoho Salt Works	MacCaughey 1917	5,6,7,12,14
Ulupa'u Burial Dunes	Buck 1964	—
10. Mōkapu Cove (Davis Point) Fishery and Salt Works (buried under runway and hangar facilities; evidence of subsurface remains documented)	Charvet-Pond & Rosendahl 1992	6,7,12,17,18

** Site is referred to in this interview*

The oral testimonies of the informants in this study attest to most individuals having knowledge regarding marine resource exploitation including, fishponds, salt gathering, and fishing practices. The retention of knowledge regarding these practices is evidence of the long-held importance of these subsistence practices that are still held today as integral aspects of the Kane`ohe Bay region by the long-term residents.

INFORMANT INTERVIEWS

A total of five individuals were interviewed for the current assessment by Melissa Lehuanani Ka`akau-Delizo and Moana Lou-Jane Lee. This section also includes the summary of an interview conducted in 1995 by Messrs. Herb Lee and Eugene Dashiell during the preparation of the Waikalua-Loko Fishpond Preservation Plan (Dashiell et al. 1995). The individuals interviewed were:

Mr. Robert Koyama –	last caretaker of Waikalua-loko Fishpond, Mr. Koyama worked for Mr. Henry Wong of Kane`ohe Ranch. He was interviewed in 1995;
Ms. Kaohua Lucas –	educational coordinator for the Waikalua-loko Fishpond Preservation Society;
Mr. Robert Miranda –	retired HPD detective, Mr. Miranda used to live on Moku-o-Loe;
Mr. Willis Motooka –	volunteer for the Waikalua-loko Fishpond Preservation Society Mr. Motooka is a retired teacher who has lived in Kane`ohe since 1958;
Mr. Fred Takebayashi –	volunteer for the Waikalua-loko Fishpond Preservation Society, Mr. Takebayashi grew up in the project region and currently lives in a subdivision on Mikiola Fishpond where his childhood home was; and
Mr. Ben Wong –	host of KHON TV's Let's Go Fishing, Mr. Wong's has family roots in Kane`ohe

INTERVIEW SUMMARIES

The summaries of each of the interviews are presented here. Complete transcripts were prepared and are kept on file at Aki Sinoto Consulting in Honolulu.

Mr. Robert Koyama

Born in 1905, Mr. Koyama was raised in Pearl City where he learned to mend fishnets. Eventually, he got involved with maintaining fishponds and decided he'd like to have his own fishpond. After the Navy moved everyone, including Mr. Koyama, out of the Naval Reservation, he and his wife moved to He'eia Kea and an area in Luluku which belonged to Kane'ohe Ranch. While raising chickens in the 1960s, he was approached by Mr. Wong, owner of Waikalua-loko fishpond who offered to turn over the fishpond to Mr. Koyama. From there on, Mr. Koyama re-stocked, managed, repaired, and improved the fishpond.

Unable to rely on the fishpond solely for subsistence, Mr. Koyama fished Kane'ohe Bay, utilizing the bay and Kane'ohe Stream to also restock his pond with *moi* and *papi'o.* While the physical conditions of the fishpond were satisfactory, the invasive and foreign mangrove was nearly impossible to control. In order to maintain a balance of fresh and salt water necessary for fishpond maintenance, Mr. Koyama piped in water from an `*auwai* (ditch) that connected Kawa and Kane'ohe Streams and ran not more than 5' from the pond. Young fish were kept in a holding pond that was adjacent to the main pond and already there when Mr. Koyama took over the pond. He repaired the wall and fixed the gates.

To control barracuda and tilapia, he would sit on his roof and fire a .22 cal rifle for a couple of hours. *Limu* was not as overgrown as it is now, but everyday he would clean out the limu which would serve as hiding places for baby tilapia. Cleaning out the *limu* would also keep the tilapia population down.

According to old Hawaiians, every pond has a "king". Mr. Koyama would see a red mullet with little black spots about ¾ pound size. This fish he would leave alone. He also stated that Dr. Wakai Chang's pond in Kahalu'u had a "king" that was a white eel.

When fishing was slow, Mr. Koyama would raise pigs and cows brought over from the Robinson Estate on Kaua'i. The area now occupied by the sewer treatment facility was grazing land. When the flood of 1965 broke his water line, the sewage plant was under construction. After speaking with the head of construction, water was then brought to Mr. Koyama by the construction crew (same line, he thinks).For this reason, his bills were paid to the Sewer Treatment Plant.

The streams were much narrower and there was a suspension bridge over Kane'ohe stream that allowed foot traffic. Cars were parked at the edge of the stream and people would walk over the suspension bridge, holding onto cables. The flood of 1965 wiped it all out.

Hawaiian Dredging put in pipes for the sewage treatment plant that went out from where the Kokokahi YWCA is now. The sewer outfall was good for fish but very bad for coral. Coral died all through the bay.

Mr. Koyama harvested about 50 lbs of fish a week, sometimes twice a week, then would not harvest for the next 4 or 5 months. Mullet was the main fish in the bay and in the pond. 'Iwa birds were a nuisance, stealing fish from the pond. He would also see wild ducks, plovers, the *'auku'u* (night heron), and the Hawaiian Stilt which is not seen much anymore.

Ms. Kaohua Lucus

Ms. Louise Ka'ohua'aionaali'i Lucas, 52 years old, is the educational coordinator for the Waikalua-loko Fishpond Preservation Society. She works regularly at the fishpond with volunteers and also the various school groups.

Ms. Lucas is not from Kane'ohe, but her *ohana* (family) originates from Ka'a'awa. They still reside there. She stated that her connection to Kane'ohe is the *loko i'a* (fish pond), Waikalua-loko, for which she has volunteered to work at for the past 10 years.

Waikalua Loko is a Hawaiian fishpond that is over 350 years old. *Kanaka* (Native Hawaiians) harvested and moved *pohaku* (stones) from the mountain of Keahiakahoe to build the fishpond wall. This type of fishpond, *loko kuapa* (shoreline walled pond) was exclusive to *ali'i* (chiefs).. *'Ama'ama* (mullet) and *awa* (milkfish), herbivorous fish, were raised for the consumption of *ali'i* and their entourage. The *makaha* (sluice grate) was designed by *kanaka* to allow *pua i'a* (fry or juvenile fish) to enter the fishpond. Once the *i'a* (fish) matured, they were unable to escape through the ½ inch slats in the makaha. Kane'ohe Bay ocean water would mix with fresh water, creating an ideal environment (brackish water) for (algae and other marine plant life to flourish) (which in turn benefitted) the herbivorous fish to live and thrive. The development of the *loko kuapa* is a major engineering feat that proved that the *kanaka* understood the rhythms of their natural world and applied this understanding.

Our *loko i'a* of Waikalua Loko is on the south end of Kane'ohe Bay. The *loko i'a* is currently being used as an educational site to teach school children and community groups about this *wahi pana* (locality or celebrated place) and the fishpond itself. Our other goal is to restore and revitalize the fishpond through community service projects.

The area of Kane`ohe Bay that I frequent is exclusively in the south end of the bay, just *makai* (seaward) of the existing sewage treatment plant at the *loko `ia*. Otherwise, I do not go to the sand bar or to other parts of the bay on a regular basis.

My knowledge regarding sewage spill into the bay is limited. I do know when heavy rains prevail, we have had problems with sewage leaking from the rusty pipes. This impacts us since we have school groups that regularly visit the fishpond. We have had to cancel several visits as a result of flooding and sewage seepage.

My greatest concern regarding the under-bay force main currently being proposed would be the duration of construction because this will definitely impact those who visit the fishpond. Will there be an alternate way to access the fishpond so we can continue receiving groups? Who will be responsible for the "funding" to create an alternate route?

I do not know much about the design of the under-bay force main. I think culturally our *kupuna* (ancestors) would have sought alternative ways to deal with the sewage problem. My concern is that once completed what kind of long-term effect will the under-bay force main have on our ocean resources as well as those of us who are stewards of fishponds? What if there is a catastrophic event when the line breaks? Is the city prepared to deal with such sewage outfalls? Again, how will this impact our ocean resources?

I would like to eventually see our *loko i'a* be used to help feed our community. At one time, our fishpond could feed 40,000 people. Hawai'i relies heavily on imported food. Over 90% of our food comes from far away. Experts say that if the container ships and barges stopped coming to Hawai'i, we would have only a seven-day supply of perishable foods on our grocery shelves. We need to move toward becoming self-sustaining. Developing farm lands and fishponds as a food sources is one way we can accomplish self-sufficiency. Perhaps, the sewage treatment plant should be converted to an aquaculture farm and the surrounding land returned to *kalo* (taro) cultivation.

Ku'u mana'o wale no... Aloha 'Aina...

Mr. Robert Miranda

Robert Miranda was born in 1954 on Moku-o-Loe, part of He'eia *ahupua'a*, where his family had resided since as early as the 1940s, until the island was turned over to the University of Hawai'i by the Pali Foundation. A former detective with the Honolulu Police Department and currently a Special Agent with the State Attorney General's Office, Mr. Miranda knows every reef and has seen the many changes that have taken place in Kane'ohe Bay.

According to Mr. Miranda, the bay was much shallower in ancient times than it is today, due to the dredging of multiple millions of cubic yards of bay floor in the 30s and 40s, probably for seaplanes. By the time he was a child, the bay was already deep.

Fishing was the main activity in the bay, and there were many fishponds along the bay shores in the 1800s. There were huge schools of fish, a hundred yards long and 20 or 30 yards wide. Bait fish. You could just step on ‘em. Throw a rock and you kill a bunch of ‘em. Outfall from the Ho’omaluhia State Park flood control caused foodchain collapse in the ponds due to in-filling with silt and by the 1950s and 60s only the Waikalualoko fishpond was in use. Kane’ohe Bay was a major fishery for both private and commercial fishing. The Hawai’i Tuna Fleet utilized the bay and also utilized a portion of Moku-o-Loe to dry nets and for bait. Residential build-up in the area of Kane’ohe Bay caused run-off that went into the bay and ruined the areas where bait would spawn. This caused a rise in tuna prices and the demise of the cannery in Hawai’i.

The proposed project area is a former oyster/clam bed area and in the 60s people from all over the island would come and get oysters and clams. Now there is no such activity and fishing has really declined in the bay as a whole. White, Samoan, and Hawaiian crab is still plentiful as the bottom of the bay is sandier than it once was.

Original sewage outfall was the river mouth. This outfall caused fish populations to grow but coral reef to die, causing reef populations to decline. Shark was once plentiful, including spawning areas in the bay for hammerhead shark. Now you don’t see that. There was an area known as Coral Gardens and lots of canoes in the bay in the old days because the water was shallow and calm. There was also a glass-bottom boat tour run by a native Hawaiian family during the 50s and mid-60s.

Mr. Miranda stated that any land route for this project would be problematic but the proposed under-bay route would not cause problems because of the decline of cultural practices, namely fishing. Recreational boaters would not really be inconvenienced because there would be no barges or other large surface vessels restricting access. He sees the project as necessary, because of population growth in the area and resulting sewage capacity needs.

Mr. Willis Motooka

I am Willis Motooka and 68 years old. I was born in Honolulu and graduated from McKinley High School in 1960. I graduated from Univ. of Hawaii in 1964 with a B.A. I was inducted into the U.S. Army and served from 1964 to 1967. I re-enrolled at the Univ. of Hawaii’s College of Education and earned a teaching certificate in science education. I taught at Stevenson Intermediate, Kailua Intermediate, and Castle High School from where I retired in 2001.

My family moved to Kaneohe in 1958. I was the youngest of 6 children. I am married and have 2 daughters and continue to live in Kaneohe. My wife, Joyce, was also a teacher and retired from Kaelepulu Elementary in 2003.

Much of Kaneohe Bay was part of the Kaneohe *ahupua`a* where numerous fishponds were built. In historic times, there were 30 fishponds along the shores of the bay which provided food such as mullets, awa, crabs, and shrimps. The construction and maintenance of the fishponds was a community effort involving all the people of the *ahupua`a*. The *ali`i* of the *ahupua`a* would mandate the people to do work at the fishponds in order to keep it functioning and stocked with fish. Fortunately, one of our *kupuna*, Fred Takebayashi, was born and raised on a fishpond in Kaneohe so we look to him for guidance.

Kaneohe Bay is a fishing destination for many commercial and recreational fishermen. That is why the bay needs to kept free of pollution and regulated so that the wetlands bordering the shore and aquatic wildlife can continue to flourish.

Mr. Fred Takebayashi

Mr. Takebayashi is who is currently 88 years old grew up and still lives in Kane`ohe today. He is currently an avid volunteer and one of the *kupuna* for the Waikalua-loko Fishpond Preservation Society. He supervises other volunteers on the restoration and maintenance work on the fishpond several days every week.

His father was a fisherman who also took care of Mikiola Fishpond located northeast of Waikalua-loko. His father used to take him to school in the mornings by boat. In the afternoon since his father was fishing, Fred would walk home along the shoreline and often walk by Waikalua-loko on his way home. He currently resides in the residential subdivision which was built on the three adjoining fishponds, including Mikiola, that were filled and used to build houses on. He still recalls when the Navy started to dredge in the bay and the spoils were brought in to fill the ponds. The spoils were piled high and apparently served to surcharge the fill because later it made an excellent foundation for houses that never sank or settled like in other reclaimed areas.

Mr. Takebayashi has worked at Waikalua-loko fishpond for a long time and has been instrumental in the stabilization and restoration undertakings, such as the wall stabilization, mangrove clearing, and continuing efforts to remove the accumulated siltation. He was also the one that located and restored the *ku`ula*, the upright stone representing the fishing god.

Unfortunately, due to scheduling and availability conflicts this interview could not be re-scheduled for completion. However, it is the current authors' understanding that the other members of the EIS team also interviewed Mr. Takebayashi. The reader is referred there for a more complete documentation of his recollections and knowledge.

Mr. Ben Wong

Mr. Ben Wong was born in Kane`ohe in 1954 and his family has been in the area for about 4 generations. Currently the host of Let's Go Fishing, the long-time fisherman has seen many changes in the Kane'ohe Bay area, some good, some not so good.

His first recollections include the fishpond and Hygenic Store that belonged to his grand aunt, Rebecca Chang. Activities that went along with fishpond management included harvesting the *makahā* for the mullet, releasing the balloon fish, killing the over-sized barracuda, catching Samoan crab, etc.

In the bay itself, Mr. Wong remembers his father and his friends doing a lot of lay-net and rod and reel fishing, dunking for bone fish, catching sea turtle, and venturing out to Mōkapu. Fishing from old wooden-plank-bottom boats with a spotter's perch built atop and kerosene-lit lanterns was a common practice during his childhood, activities not seen today.

There was a 2-3 year run on oysters and clams on the Kokokahi side of the bay in the 60s. Harvesting these shellfish caused so many to be crushed that giant white crabs would come out at night and feast on the damaged clams. In 45 minutes Mr. Wong and his family could easily gather 5 mop buckets of giant white crabs, "so big they couldn't fit flat on the bottom of a bucket."

According to Mr. Wong, the sewage effluent from the Marine Base and Kailua affected the health of the bay in the 60s. *E.coli* counts rose causing a jump in fish populations but killed off the coral. Plankton and jellyfish populations also rose, making the bay inhospitable to humans. Green sea leaf lettuce, once plentiful, began to disappear from the bay shorelines and the *opai* became scarce. The introduction of saltwater tilapia that escaped the Kahalu`u fishpond from a fishery endeavor about 15 or 20 years ago also caused a decrease in *opai*. However, Mr. Wong indicates that today there may be as much *moi* in the bay as there was during his childhood, perhaps due to a combination of efforts by the Oceanic Institute and a decrease in market demand for wild *moi*.

Mr. Wong indicates that there has been a lot of healing in the bay. Namely, the coral has been replanted and has grown so much that there are now more navigational hazards in the bay. Outside the fringing reef, just He`eia side of King Intermediate School, is a little channel that is getting smaller and smaller. According to Mr. Wong, the reefs will soon connect and prevent navigation through that area. He states that unknowing boaters are unaware of the build-up of the reefs and he has had to pull off many an unsuspecting boater who made an error in judgment. He cites storm run-off for the build-up of silt that is also causing depth changes and navigational hazards. The regular storm run-off is something that needs to be addressed, just as the issue of sewage effluent does.

Because the proposed route of the project is under-bay, he doesn't see an issue with recreational yachters, so long as the route circumvents the area most commonly used by them. Also, the canoe paddlers launch from He`eia Kea and don't utilize much, if any, of the bay as they did in the old days. Mr. Wong brings out an interesting point: anything put into the bay becomes a habitat and contributes to the growth of fish populations. Look at any artificial reef put in for submarine tours. The growth of fish may attract people back into the water to engage in Hawaiian cultural practices once again. This project will hopefully accomplish more than just controlling sewage in Kane`ohe Bay.

DISCUSSION OF INTERVIEWS

As pointed out in the discussion of the historical background, Kane'ohe Bay itself was regarded as one of the most important fisheries in the entire Hawaiian chain from ancient times. The current interviews presented the role of the bay in more recent times from the perspective of these individuals.

According to several long-time residents and fishermen, the importance of Kane'ohe Bay for subsistence and recreational activities has changed drastically over the past 50 years. Its importance to modern yachters and other recreational boaters not withstanding, the bay's importance as a major fishery has waned since populations of native Hawaiian fish, imported oysters, and clams decreased rapidly with the introduction and proliferation of tilapia and other predatory species of fish together with the various man-made adverse environmental effects.

According to Mr. Robert Miranda, born on Moku-o-Loe and still a resident of Kane`ohe, the increase in sewage runoff in the fifties and sixties, when more people moved into the area, actually resulted in higher numbers of certain kinds of fish, including hammerhead sharks. Leafy seaweed was common along shoreline areas of the bay and the Waikalua-loko fishpond was still in use into the sixties. Commercial tuna boats operated in the bay and Moku-o-Loe (Coconut Island) was used for drying commercial fishing nets. All this activity made Kane'ohe Bay a crucial part of marine subsistence for the people of O`ahu, well into the late sixties.

The last several decades have seen reductions in Hawaiian cultural practices in the bay, with canoe paddling activities mainly limited to the He`eia Kea Boat Harbor or the central bay. Nowhere in the bay does one see fishing from canoes as commonly as Ben Wong did when he was a child in the late fifties and early sixties, fishing with his family from old wooden boats with kerosene lanterns. Gone are the days when Robert Koyama tended his fishpond in the bay, seeing the rare red mullet and the white eels, trying his best to keep the foreign tilapia out of the pond.

Years of siltation, sewage run-off, and the effects of wide-spread dredging had caused the decimation of the coral reef, especially in the south bay in the sixties and seventies. According to Mr. Ben Wong, the recent use of scientific techniques for revitalizing the coral reef (i.e., transplanting) has actually had the negative effects of making certain areas of the bay un-navigable. He's had to pull many a recreational boater off coral and silt that have built up in the bay over the last 15 or so years, and suggests that most boaters are completely unaware of the major changes that have occurred due to these projects. The opinion of many people not familiar with effects of sewage runoff on marine populations is that there are no fish in the bay and, even if there are, you do not want to eat them. Mr. Wong and other fishermen suggest that this is a good thing because overfishing is avoided, leaving only those long-time diehards who know the bay well, out there fishing, while others are engaged in recreational yachting or other activities. He suggests that, instead of being worried about possible adverse affects of this project, boaters need to be more concerned about navigational dangers from silt build-up and coral overgrowth.

Although the shoreline areas of Kane'ohe Bay once flourished with fishponds, the only one in recent memory that was still in use was Waikalua-loko. The use of holding ponds adjacent to the main pond was an ancient Hawaiian practice that Robert Koyama continued as he painstakingly worked to repair and keep the pond free of the foreign and invasive mangrove, frogs, tilapia, and predatory barracuda. He remembers the *`iwa* and *`auku`u* often coming into the pond to try to steal a meal but now they never come. According to Robert Miranda, the natural food-chain and freshwater-saltwater relationship necessary to keep a fishpond healthy and well-stocked for subsistence has long been destroyed by flood water outfall, mangrove introduction, and a lack of interest or need to keep a fishpond in working condition. The flood of 1965 all but destroyed Waikalua-loko fishpond, though Mr. Koyama worked very hard to repair it. It is now tended to by a non-profit, steward organization that delegates a volunteer groups of adults and students who are slowly cleaning out the mangrove, stabilizing the walls, and slowly restoring the pond. However, in the opinion of the interviewees, most likely it will never return to be a resource for subsistence or commercial fishing as in the past.

The current project, according to these long-time fishermen and residents of the area, does not pose a threat to cultural practices, since no obvious cultural practices appear to take place in the bay anymore. Outrigger paddlers stay closer to He'eia Kea rather than utilize major portions of the bay and fishermen are much fewer than decades ago. Yachters, according to our informants, should not have an issue with the project as proposed, since it will be an under-bay project not requiring barges or structures that will restrict areas on the surface of the bay that would adversely affect their activities. Only in the event of an emergency would over-water operations be required.

The collective opinion for the majority of those interviewed was that since sewage control impacts public health as well as the welfare of marine life, the under-bay route for the project can benefit the bay and its residents. None of the individuals interviewed foresaw any specific negative impacts upon either the public or marine resources other than the potential ramifications of an inadvertent catastrophic failure of the proposed system. More of a concern to our informants is the periodic flood run-off from the Kawa and Kane`ohe Streams that causes silt build-up in the bay. As Mr. Ben Wong indicated, the health of coral populations has risen to such a high level and the fish population has slowly increased (though it may be kept as a bit of a secret) so that any threat of adverse affect would come from NOT doing the project.

CONCLUSIONS

During the course of the current undertaking, in addition to seeking out knowledgeable individuals and pertinent community entities, attendance and participation in several community meetings were undertaken to fulfill some of the protocols included in the impact assessment guidelines. These included the Waikalua-loko Fishpond Preservation Society Board meeting, the

Kane`ohe Bay Regional Council meeting, an informational briefing to the O`ahu Island Burial Council, Community Working Group meetings convened by the project EIS team, consultation meetings with staff from the State Historic Preservation Division of the Department of Land and Natural Resources including a field inspection of the project area, and a meeting with representatives of the neighboring Kokokahi YWCA for an informational briefing of the project as well as discussion of potential interim access to the pond during the duration of construction activities on the artificial peninsula where the community activities are normally staged. Through these meetings a wide range of community as well as other interested groups and stakeholders were informed of the scope of the proposed project and opportunities were provided for the interchange of information, input, and commentary.

As demonstrated by the various information provided in the preceding sections of this report, the long term cultural practices in the south bay region of Kane`ohe Bay consisted of land and ocean based subsistence activities such as farming, gathering, aquaculture, and fishing. The advent of mid to late historic period and modern human activities have adversely impacted the land surrounding the bay as well as the bay itself which in turn severely impacted these subsistence practices both during the historic as well as the modern periods. Today, most such activities are of a recreational nature, whether for residents or for visitors. The *Kane`ohe Bay Master Plan* document prepared by the Kane`ohe Bay Master Plan Task Force in 1992, includes an overview of activities in the south bay. This study lists twenty localities along the shoreline between the two land segments of Waikalua and Aikahi for the proposed underbay force main corridor (1992:60). The twenty localities represent nine different categories of activities consisting of pole and line fishing (5), sailing (3), throw-netting (3), gill netting (2), crabbing (2), aquatic recreation (2), torch fishing (1), trapping (1), and seaweed gathering (1).

Current observations confirm that these types of activities still take place in the project region in essentially the same frequencies indicated, although throw netting and lay or gill netting activities were not seen. In comparison to other areas of the bay, the frequency and diversity of such activities are markedly lower in the south bay. Regarding such activities, the proposed under-bay force main project would only minimally affect access to the immediate shoreline area of the artificial peninsula located between the mouth of Kane`ohe Stream and Waikalua-loko Fishpond. All other segments of the transmission corridor will have no effect on the surface of the southern sector of Kane`ohe Bay. Over-water, construction-related activities would only be implemented if warranted in the event of an emergency during construction.

Based on the collective results of the historic research, the interviews, and input received from meetings; no specific adverse cultural impacts have been raised. The majority of the public opinion regarding the project have been positive, especially citing the need for upgraded waste water handling and also addressing public health and safety concerns. Only one general objection citing desecration of the *aina* and the *kai* was raised by two community members regarding the gravity tunnel and the current force main proposals. The majority of the community concerns focused on restricted marine traffic within the bay. However, these concerns were alleviated when project engineers determined that no over-water structures, floating pipes, or other obstructions would be on the surface of the bay other than in the event of an emergency that requires over-water procedures to be implemented.

Thus, the results of the current assessment procedure strongly indicate that no adverse impacts to traditional or contemporary cultural practices will be brought about by the implementation of the proposed Kane`ohe/Kailua Force Main No. 2 Project.

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Appendix H

Cultural Impact Assessment for the Proposed Kaneohe – Kailua Wastewater Conveyance and Treatment Facilities Project Alternative 2 – Tunnel Route
Kaneohe Ahupuaa, Koolaupoko District, Oahu Island
Cultural Surveys Hawaii, Inc.
November 2010

Cultural Impact Assessment for the Proposed Kāneʻohe-Kailua Wastewater Conveyance and Treatment Facilities Project, Alternative 2–Tunnel Route, Kāneʻohe Ahupuaʻa, Koʻolaupoko District, Oʻahu Island

TMK: [1] 4-2-15, 17; 4-4-11, 12; 4-5-30, 31, 32, 38, 100 & 101: various parcels

Prepared for

Wilson Okamoto Corporation

Prepared by

Joseph H. Genz, Ph.D.

and

Hallett H. Hammatt, Ph.D.

Cultural Surveys Hawaiʻi, Inc.

Kailua, Hawaiʻi

(Job Code: KANEOHE 15)

January 2011

Oʻahu Office
P.O. Box 1114
Kailua, Hawaiʻi 96734
Ph.: (808) 262-9972
Fax: (808) 262-4950

www.culturalsurveys.com

Maui Office
1860 Main St.
Wailuku, Hawaiʻi 96793
Ph: (808) 242-9882
Fax: (808) 244-1994

Prefatory Remarks on Language and Style

A Note about Hawaiian and other non-English Words:

Cultural Surveys Hawaiʻi (CSH) recognizes that the Hawaiian language is an official language of the State of Hawaiʻi, it is important to daily life, and using it is essential to conveying a sense of place and identity. In consideration of a broad range of readers, CSH follows the conventional use of italics to identify and highlight all non-English (i.e., Hawaiian and foreign language) words in this report unless citing from a previous document that does not italicize them. CSH parenthetically translates or defines in the text the non-English words at first mention, and the commonly-used non-English words and their translations are also listed in the *Glossary* (Appendix A) for reference. However, translations of Hawaiian and other non-English words for plants and animals mentioned by community participants are referenced separately (see explanation below).

A Note about Plant and Animal Names:

When community participants mention specific plants and animals by Hawaiian, other non-English or common names, CSH provides their possible scientific names (Genus and species) in the *Common and Scientific Names of Plants and Animals Mentioned by Community Participants* (Appendix B). CSH derives these possible names from authoritative sources, but since the community participants only name the organisms and do not taxonomically identify them, CSH cannot positively ascertain their scientific identifications. CSH does not attempt in this report to verify the possible scientific names of plants and animals in previously published documents; however, citations of previously published works that include both common and scientific names of plants and animals appear as in the original texts.

Abbreviations

APE	Area of Potential Effect
CIA	Cultural Impact Assessment
CSH	Cultural Surveys Hawai‘i
DOH	Department of Health
HAR	Hawai‘i Administrative Rules
HRS	Hawai‘i Revised Statutes
LCA	Land Commission Award
OEQC	Office of Environmental Quality Control
OHA	Office of Hawaiian Affairs
OIBC	O‘ahu Island Burial Council
SHPD	State Historic Preservation Division
TCP	Traditional Cultural Property
TMK	Tax Map Key
USGS	United States Geological Survey
WWPTF	Wastewater Pre-Treatment Facility
WWTP	Wastewater Treatment Plant

Management Summary

Reference	Proposed Kāneʻohe-Kailua Sewer Tunnel Project, Alternative 2–Tunnel Route, Kāneʻohe Ahupuaʻa, Koʻolaupoko District, Oʻahu Island (TMK: [1] 4-2-15, 17; 4-4-11, 12; 4-5-30, 31, 32, 38, 100 & 101: various parcels (Genz and Hammatt 2011)
Date	January 2011
Project Number	CSH Job Code: KANEOHE 15
Agencies	State of Hawaiʻi Department of Health/Office of Environmental Quality Control (DOH/OEQC)
Project Location	The approximately three-mile long subsurface Project corridor will be aligned to traverse mostly under the Oneawa Hills range *mauka* (inland) of Kaneohe Bay Drive.
Land Jurisdiction	The City and County of Honolulu owns the Kāneʻohe Wastewater Pre-Treatment Facility (WWPTF) and the Kailua Regional Wastewater Treatment Plant (WWTP); the Board of Water Supply owns the location of a proposed tunnel access shaft; and Kaneohe Ranch owns most of the land of Oneawa Hills.
Project Description	The City and County of Honolulu Department of Environmental Services proposes to undertake improvements to the wastewater collection and treatment system in the Kāneʻohe-Kailua wastewater service area. The proposed Project involves the construction of a new conveyance system to supplement an existing force main carrying pre-treated wastewater from the Kāneʻohe WWPTF to the Kailua Regional WWTP. The proposed Alternative 2–Tunnel Route involves construction of an approximately 13-foot diameter tunnel between the two facilities. The floor of the tunnel would begin at a depth of approximately 35 feet below sea level at the Kāneʻohe WWPTF. It would traverse approximately three miles, mostly beneath the Oneawa Hills range, reaching a floor depth of approximately 62 feet below sea level at the Kailua Regional WWTP, where the wastewater will be pumped to the surface for treatment by a new influent pump station. In addition to conveying wastewater by gravity flow, the tunnel would also serve a storage function when the volume of wastewater increases during periods of high rainfall. The tunnel alternative would allow the existing Kāneʻohe WWPTF and existing force main to be taken out of service. The proposed sewer tunnel would be constructed by tunnel boring machinery and could be staged from either the Kāneʻohe WWPTF or the Kailua Regional WWTP. An intermediate tunnel access shaft would also be constructed near the midpoint of the tunnel.
Project Acreage	Approximately three miles in length.
Area of Potential Effect (APE) and	For the purposes of this Cultural Impact Assessment (CIA), the APE is defined as the approximately three-mile long Project area. While this

Survey Acreage	investigation focused on the Project APE, the study area included the entire *ahupua‘a* (land division usually extending from the uplands to the sea) of Kāne‘ohe.
Document Purpose	The Project requires compliance with the State of Hawai‘i environmental review process (Hawai‘i Revised Statutes [HRS] Chapter 343), which requires consideration of a proposed Project’s effect on cultural practices and resources. Wilson Okamoto Corporation requested CSH conduct this CIA. Through document research and ongoing cultural consultation efforts, this report provides information pertinent to the assessment of the proposed Projects’ impacts to cultural practices and resources (per the *Office of Environmental Quality Control’s Guidelines for Assessing Cultural Impacts*) which may include Traditional Cultural Properties (TCPs) of ongoing cultural significance that may be eligible for inclusion on the State Register of Historic Places, in accordance with Hawai‘i State Historic Preservation Statute (Chapter 6E) guidelines for significance criteria according to Hawai‘i Administrative Rules (HAR) §13-275 under Criterion E. The document is intended to support the Project’s environmental review and may also serve to support the Project’s historic preservation review under HRS Chapter 6E and HAR Chapter 13-275.
Consultation Effort	Hawaiian organizations, agencies and community members were contacted in order to identify potentially knowledgeable individuals with cultural expertise and/or knowledge of the Project area and the vicinity. The organizations consulted included the State Historic Preservation Division (SHPD), the Office of Hawaiian Affairs (OHA), the O‘ahu Island Burial Council (OIBC), Hui Mālama I Nā Kūpuna ‘O Hawai‘i Nei, the Ko‘olaupoko Hawaiian Civic Club, and community members of Kāne‘ohe Ahupua‘a.
Results of Background Research	Background research for this Project yielded the following results (presented in approximate chronological order): 1. The early settlers of the Hawaiian archipelago would have been attracted to the windward *moku* (district) of Ko‘olaupoko on O‘ahu, especially the *ahupua‘a* of Kāne‘ohe, with its coral reefs, bays, and inlets for fishing, dense basalt dikes for the production of stone adzes and other tools, and amphitheatre-like basins and broad alluvial floodplains that contained fertile soils, permanently flowing streams, and high rainfall for the cultivation of crops (Kirch 1985:69). In Ko‘olaupoko, the sand dunes of Bellows Beach (A.D. 300–400) in Waimānalo Ahupua‘a (Kirch 1985:69–80) and Luluku (A.D. 500) in Kāne‘ohe Ahupua‘a (Allen 1987:265) are among the earliest Hawaiian archaeological sites. An archaeological site in close

	proximity to the Kāneʻohe WWRTF contains a vast assemblage of lithic artifacts radiocarbon dated to A.D. 1070–1405, which suggests that this area housed craftsmen specializing in the production of adzes and other stone tools (Clark and Riford 1986). Archaeological sites at Nuʻupia Fishpond adjacent to the Kailua WWTP similarly contain basalt tools, adze blanks, and flakes associated with stone tool manufacture (Hammatt et al. 1985; Jackson et al. 1993). Very few marine shellfish midden were recovered archaeologically, which suggests that Hawaiians once lived near the fishpond on a temporary or periodic basis (Jackson et al. 1993:78). 2. The settlers' descendants developed *loʻi kalo* (irrigated taro terraces) and other forms of agriculture, including the cultivation of *ʻuala* (sweet potatoes), *uhi* (yam), *maiʻa* (banana), *hala* (pandanus), *wauke* (paper mulberry), *ōlonā* (a native shrub used for cordage), and *ʻawa* (kava) (Handy and Handy 1972:456), and built at least 30 *loko iʻa* (fishponds) in the brackish waters of Kāneʻohe Bay for the harvesting of *ʻamaʻama* (mullet), *awa* (milkfish), and other fish (Devaney et al. 1982:114, 143–144; Summers 1964:2). Recent archaeological surveys near the Kāneʻohe WWRTF documented a taro terrace (Clark and Riford 1986) and subsurface agricultural soil indicative of taro production (Hammatt and Borthwick 1989). 3. Kāneʻohe Ahupuaʻa contains numerous *wahi pana* (storied places) and associated *moʻolelo* (stories, oral traditions) that place the specific Project area within a broader cultural context. One *moʻolelo* in particular illuminates the entire landscape of the *ahupuaʻa*, from the mountain peaks (Keahiakahoe) and upland forests (Puʻu Kahuauli) to the coastal waters (Puʻu Pahu) and offshore islands (Moku o Loe) by chronicling a sibling rivalry (Hawaiian Ethnological Notes ms. Vol. 2:2181, cited in Sterling and Summers 1978:206; Landgraf 1994:94). Several *wahi pana* are located in the vicinity of the Kāneʻohe WWPTF and the Kailua WWTF, as well as on the *ʻili* of Waikalua, Keana, Mahinui, Kalāheo, Paʻalae, Pūʻahuʻula, Mālaʻe, and ʻAikahi (Lyons 1876; Wall 1914) above the subsurface Project corridor along the Kāneʻohe Bay shoreline. Waikalua Loko Fishpond, located immediately *makai* (seaward) of the Kāneʻohe WWPTF, measures over 1,400 feet in length and contains four *mākāhā* (sluice gates) (McAllister 1933:176). Laʻa, a navigator from Kahiki—the ancestral

	homeland of Hawaiians and other Polynesians—arrived nearby on the north side of the mouth of Kāneʻohe Stream, which was called Nāonealaʻa (sands of Laʻa) and is now Kāneʻohe Beach Park (Kamakau 1867; Thrum 1916:90). In the twelfth century, the *aliʻi* (chief) ʻOlopana erected the massive structure of Kāwaʻewaʻe Heiau, located about one mile east of the Kāneʻohe WWPTF, to sacrifice the pig demigod Kamapuaʻa (Kalākaua (1990:142–147; McAllister 1933:179; Thrum 1916:90). Nuʻupia Fishpond, located immediately north of the Kailua WWTF, and two adjacent fishponds (Halekou and Kaluapuhi) once separated Mōkapu from the main land of Kāneʻohe (McAllister 1933:184). 4. On the leeward half of Mōkapu Peninsula in Kāneʻohe Ahupuaʻa, excavations in the mid-twentieth century unearthed over 1000 *ilina* (burials) in the sand dunes (Kirch 1985:111). The Mōkapu dunes were most likely established burial grounds for the residents of several villages located on the windward half of the peninsula in Heʻeia Ahupuaʻa (Sterling and Summers 1978:217). A limestone cobble pavement close to the northern boundary of the Kailua WWTP may cover a burial (Jackson et al. 1993), but there is no documented evidence from archaeological surveys, historical records or oral traditions of *ilina* or *iwi kūpuna* (ancestral remains) within the Project area. 5. In the 1780s, Kahekili, the *mōʻī* (king) of Maui, met and defeated Kahahana, the *mōʻī* of Oʻahu, in the valley of Nuʻuanu, and after his victory he lived at Kailua while most of his *aliʻi* (chiefs) and followers stayed in Kāneʻohe and Heʻeia (Kamakau 1992:138). In 1795, Kamehameha similarly met Kalanikupule in Nuʻuanu Valley during his invasion of Oʻahu, and after his victory at the Battle of Nuʻuanu, he retained the *ahupuaʻa* of Kāneʻohe and Heʻeia as his own personal property (ʻĪʻī 1959:69–70). 6. The most impressive *ala hele* (trail) in the *ahupuaʻa* of Kāneʻohe formerly traversed the sheer cliff rocks of the Nuʻuanu Pali to the base of the mountains. Hawaiians used this steep path to transport taro, *poi* (pounded taro), potatoes, chickens, goats, and pigs between Honolulu to windward Oʻahu (Thrum 1901:89). Kamehameha III, in response to agricultural development in Kāneʻohe and other *ahupuaʻa* on windward Oʻahu, secured funds in 1845 to make the trail accessible to horses by paving the path with stones. In 1882, construction began to widen and reduce the grade of the road. The improved

	Pali Road opened in 1897 after workers found an estimated 800 skulls along with other bones at the bottom of the Pali—the remains of the warriors defeated by Kamehameha in 1795 (*Island Call* 1953). The road was maintained for 55 years until work began in 1952 to construct a new four-lane highway with two tunnels running under the site of the Nuʻuanu battle (Devaney et al. 1982:172). 7. The middle nineteenth century marked the introduction of private and public land ownership laws to Hawaiian society during the Māhele (division of Hawaiian lands). No *kuleana* (Native Hawaiian land rights) claims were awarded near the Kailua WWPT, but testimonies associated with Land Commission Awards (LCAs) reveal that Hawaiians used the land near the Kāneʻohe WWPTF primarily to grow taro and *kula* (dryland) crops and had built *loko iʻa* along the coast of Kāneʻohe Bay (Waihona ʻAina 2000). The coastal flat area between Kāneʻohe and Kawa Streams immediately *mauka* of the Waikalua Loko Fishpond, known as the Waikalua Swamp and now the site of the Kāneʻohe WWPTF, was an area of intense production of taro. Claimants who resided in other *ʻili* with less reliable sources of fresh water tended to maintain *loʻi* in the Waikalua Swamp area as *lele* (a detached part or lot of land belonging to one *ʻili* and located in another) (Waihona ʻAina 2000). 8. Successive eras of commercial rice and sugar cultivation, ranching, pineapple farming, and dairy farming transformed the land of Kāneʻohe Ahupuaʻa. In particular, ranching in the mid-nineteenth century, which extended from the ocean to the *pali*, quickly caused environmental degradation and severely modified the landscape in the *mauka* regions (Devaney et al. 1982). Japanese and other immigrant families converted the *loʻi kalo* to rice paddies and sugar cane fields in the late nineteenth century, and pineapple field clearance in the early twentieth century likely destroyed many archaeological sites in the *mauka* regions (Kelly 1987). 9. Descendants of immigrant families, such as Joe Takebayashi (Fanning 2008:82–90) and Kenneth Fusao Wakabayashi (Fanning 2008:94–106), fished and hunted crabs throughout Kāneʻohe Bay in the early 1900s. Their testimonies also indicate how that the Japanese utilized the *mākāhā* of fishponds to store their catch and formed fishing "camps" along the

	waterfront. 10. Following World War II, residential developments in Heʻeia expanded. The U.S. military filled in six *loko iʻa* in Kāneʻohe Bay to provide land for residential lots (Dorrance 1998:95). The newly constructed Wilson Tunnel on the Likelike Highway and the expansion of the Pali Highway in the 1950s and 1960s allowed easier access from Honolulu through the Koʻolau Mountains to windward communities, and this led to increased residential developments. The Kāneʻohe sewage treatment plant was constructed in 1963, converted to a wastewater pump station in 1978, converted to a preliminary treatment facility in 1994, and upgraded in 1998. The Kailua WWTP was built in 1965 and expanded in 1994 (City and County of Honolulu 2009).
Results of Community Consultation	CSH attempted to contact 35 community members and government agency and community organization representatives. Of the 14 people that responded, four *kūpuna* (elders) and/or *kamaʻāina* (Native-born) participated in formal interviews for more in-depth contributions to the CIA. CSH also presented the Project information to the Koʻolaupoko Hawaiian Civic Club and the OIBC. This community consultation indicates: 1. *Kamaʻāina* of Kāneʻohe Ahupuaʻa associate the vicinity of the Project area with several *wahi pana* and *moʻolelo*, which reveals a strong connection to past traditions and a renewed salience of those traditions today. For example, Ms. Cypher and Mr. Wolfgramm recall *moʻolelo* of Nāonealaʻa, the sands of the navigator Laʻamaikahiki (Laʻa). Mr. Wolfgramm adds that to provide a smooth landing place for his canoes, Laʻamaikahiki ordered his followers to mine the black cinder lava on Mōkapu and then transport the sands by canoe, a feat that required over 3000 crossings of Kāneʻohe Bay. Years later, according to Ms. Cypher, Nāonealaʻa was the site of a peace-making process. Mr. Wolfgramm also notes that Mālaʻe, a peninsula along the Kāneʻohe shoreline, provided a suitable landing area and tactics training for Nāonealaʻa marine and army units, and currently marks an anchorage for voyaging ships. According to Ms. Cypher, *moʻolelo* also describe that the gods created the first man out of the sands of Mōkapu. 2. A strong connection to ancestral land is based on lived experiences with *loʻi kalo*. Mrs. Hewett and Mrs. Kaluhiwa recall the intense productivity of the taro fields during their

	childhoods in the *mauka* lands of Ha‘ikū and the *makai* lands near He‘eia Fishpond, respectively. Mrs. Hewett’s family prepared taro in a variety of ways as their staple food, including steamed taro and taro hotcakes, and they sold *poi*. She recollects how the freshwater springs and rivers created a natural wetland region for taro production. Mrs. Kaluhiwa notes the remnants of two *poi* mills near He‘eia Fishpond. Now, under the auspices of the Ko‘olaupoko Hawaiian Civic Club, Mrs. Kaluhiwa and Mrs. Hewett are spearheading an initiative to restore the vast *lo‘i kalo* of their childhood. 3. The Ha‘ikū lands of He‘eia Ahupua‘a and other *mauka* regions in Kāne‘ohe Ahupua‘a supported an abundance of papaya, banana, and bamboo, as well as medicinal plants. Mrs. Hewett and Mrs. Kaluhiwa recount how their families gathered plants for Hawaiian medicines, such as *‘ōlena* (turmeric) and *māmaki* (an endemic nettle) (See Appendix B for scientific and common names of plants and animals mentioned by community participants). Mrs. Kaluhiwa also describes a family burial cave high on the ‘Ioleka‘a mountain cliffs in He‘eia Ahupua‘a that may have been accessed with *hau* (beach hibiscus) rope, and shares a poignant childhood memory of using flowers including *puakenikeni* (perfume flower), *pikake* (Arabian jasmine), and *pakalana* (Chinese violet) trees to fragrantly incense the family’s outhouses. 4. The *kama‘āina* of Kāne‘ohe and He‘eia Ahupua‘a also had access to the marine and freshwater resources of Kāne‘ohe Bay. Mrs. Kaluhiwa caught *āholehole* (young stage of the *āhole*, Hawaiian flagtail), *weke* (goatfish), *‘ama‘ama* (striped mullet), *awa* (milkfish), and *manini* (convict tang), gathered *‘ōpae lōlō* (brackish-water shrimp) and oysters, and hunted a variety of crabs, including *‘a‘ama* on the shore rocks and *haole* crabs and *kūhonu* farther offshore. Mrs. Hewett also fished and hunted for crabs and, with access to He‘eia Fishpond, caught and consumed *‘ō‘io* (ladyfish, bonefish), while Mr. Takebayashi raised mullet in Waikalua Loko Fishpond and Mikiola Fishpond. Mrs. Hewett also recollects that the taro fields once maintained populations of *‘ōpae* (freshwater shrimp), which she used to collect with the spine of a coconut palm. 5. Japanese immigration and the eras of pineapple cultivation, rice cultivation, and the dairy industry have significantly added to the character of Kāne‘ohe. Mrs. Hewett recalls several Japanese dairy farming families who sold their produce at

	stands on the old Pali Road, and Mr. Takebayashi acknowledges his father and other Japanese who were the stewards of Waikalua Loko Fishpond. 6. Ms. Cayan, representing SHPD, is concerned that the proposed Project may uncover burials or other cultural resources that may have been covered by the construction of the Kāneʻohe WWPTF and the Kailua Regional WWTP, and that the boring technology may penetrate into unknown cultural resources, including possible burials. More specifically, Ms. Cypher states that the construction of the proposed Project may impact the cultural sites and areas of Waikalua Loko Fishpond, Nāonealaʻa, the ridge separating the *ahupuaʻa* of Kāneʻohe and Kailua, and Mōkapu. 7. Ms. Cypher is concerned about allowing additional population growth in an area already heavily populated, and also seeks better protection for the natural and cultural resources of Kāneʻohe Bay. She believes that if the proposed Project enables more people to live in the region beyond current trends in natural population growth, there would be cultural impacts on Native Hawaiians and descendants of the earliest immigrant families, including the possibility of an increase in crime, a decreased connection to natural resources, decreased access to fishing grounds and gathering places, pressure to develop more in Kāneʻohe and along the northern coast of Koʻolaupoko Moku, more competition for affordable housing, and the loss of land. In addition, Ms. Cypher is concerned that excavated material will overflow into the bay and adversely impact fishing, crabbing, and clamming areas. 8. Mr. Wolfgramm draws inspiration from the *ʻōlelo noʻeau* (proverb), "*Ka ulu koa ikai o Oneawa* (The *koa* grove at the seaside of Oneawa) and his current practices in Waiāhole Valley to suggest that the barren landscape of Oneawa Hills be restored to a sustainable native Hawaiian forest.
Impacts and Recommendations	Based on the information gathered for the cultural and historic background and community consultation detailed in this CIA report, CSH foresees potential impacts of the proposed Project on Native Hawaiian or other ethnic groups' cultural practices customarily and traditionally exercised for subsistence, cultural or religious purposes, and on cultural, historic, and natural resources. CSH clarifies these impacts and makes the following recommendations:

	1. Land-disturbing activities may uncover burials or other cultural resources that have been covered by the current wastewater systems, and the boring technology may penetrate into unknown cultural resources, including possible burials. The Kāneʻohe WWPTF is located near the Waikalua Loko Fishpond and Nāoneala'a, and the Kailua WWTF is located near Nuʻupia Fishpond and Mōkapu. Archaeological surveys in the vicinity of these two areas have uncovered evidence of stone tool production and habitation (Clark and Riford 1986; Hammatt et al. 1985; Jackson et al. 1993), as well as a possible burial near the Kailua WWTP (Jackson et al. 1993). Further, the Kailua WWTP is located adjacent to Jaucus sand deposits, which often contain burials throughout the Hawaiian Islands. Should historic, cultural or burial sites or artifacts be identified during ground disturbance, the City and County of Honolulu, or its agent, should immediately cease all work and notify the appropriate agencies pursuant to applicable law. 2. Cultural practices, such as fishing, crabbing, and clamming, and recreational activities, such as paddling and sailing, occur along the coast and in the waters of Kāneʻohe Bay. If construction of the proposed Project (e.g. removal of excavated material from the proposed tunnel) results in adverse water quality (e.g., silt, sewage) of the rivers, fishponds, and bay waters near the Kāneʻohe WWPTF and the Kailua WWTF, there may be impacts to these resources and activities. The City and County of Honolulu should implement best management practices to avoid or reduce impacts of the Project construction on the marine environment and nearby water-based cultural and recreational activities. 3. The boring of the proposed tunnel involves the extraction of a substantial amount of crushed basalt rock, which will need to be transported off-site. Although CSH is not aware of any cultural practices that currently take place along the major roads in the vicinity of the Kāneʻohe WWPTF or the Kailua Regional WWTF, the City and County of Honolulu and Wilson Okamoto Corporation should consult with community organizations and implement best management practices to avoid or reduce impacts of the removal of excavated material (e.g., high volume of dump trucks and associated increase in noise disturbance and blowing dust) on any cultural practices (e.g., prayers, gathering of medicinal plants).

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Section 1 Introduction

1.1 Project Background

At the request of Wilson Okamoto Corporation, Cultural Surveys Hawaiʻi (CSH) is conducting a Cultural Impact Assessment (CIA) for the Proposed Kāneʻohe-Kailua Wastewater Conveyance and Treatment Facilities Project, Alternative 2–Tunnel Route, Kāneʻohe Ahupuaʻa, Koʻolaupoko District, Oʻahu Island (TMK: [1] 4-2-15:09; 4-2-17:01, 16, 18, 21; 4-4-11:03, 81, 82, 83; 4-4-12:01, 02, 64, 65; 4-5-30:01, 36; 4-5-31:76; 4-5-32:01; 4-5-38:01; 4-5-100:01, 02, 03, 04, 52; 4-5-101:33, 34, 35, 36, 37, 38) (Figure 1 to Figure 6). The approximately three-mile long Project will be aligned to traverse mostly under the Oneawa Hills range *mauka* (upland) of Kaneohe Bay Drive.

The City and County of Honolulu Department of Environmental Services proposes to undertake improvements to the wastewater collection and treatment system in the Kāneʻohe-Kailua wastewater service area. The proposed Project involves the construction of a new conveyance system to supplement an existing force main carrying pre-treated wastewater from the Kāneʻohe Wastewater Pre-Treatment Facility (WWPTF) to the Kailua Regional Wastewater Treatment Plant (WWTP). An alternative solution involves the construction of a force main.

The proposed Alternative 2–Tunnel Route involves construction of an approximately 13-foot diameter tunnel between the two facilities. The floor of the tunnel would begin at a depth of approximately 35 feet below sea level at the Kāneʻohe WWPTF. It would traverse approximately three miles, mostly beneath the Oneawa Hills range, reaching a floor depth of approximately 62 feet below sea level at the Kailua Regional WWTP, where the wastewater will be pumped to the surface for treatment by a new influent pump station. In addition to conveying wastewater by gravity flow, the tunnel would also serve a storage function when the volume of wastewater increases during periods of high rainfall. The tunnel alternative would allow the existing Kāneʻohe WWPTF and existing force main to be taken out of service.

The proposed sewer tunnel would be constructed by tunnel boring machinery and could be staged from either the Kāneʻohe WWPTF or the Kailua Regional WWTP. An intermediate tunnel access shaft would also be constructed near the midpoint of the tunnel. Near-surface land disturbance associated with the proposed Project would occur in the vicinity of the Kāneʻohe WWPTF, the intermediate access shaft, and the Kailua Regional WWTP. Horizontal boring associated with the construction of the sewer tunnel would occur at depths greater than 45 feet and would likely have no effect on the near-surface sediments above. Spoils comprised mostly of unweathered basalt generated by the boring will be extracted through the completed portion of the tunnel. The basalt will be removed as crushed rock, which can be readily processed for use as construction material.

Figure 1. Portion of the orthoimagery of the 2005 U.S. Geological Survey (USGS) 7.5-minute topographic quadrangle showing the Project area

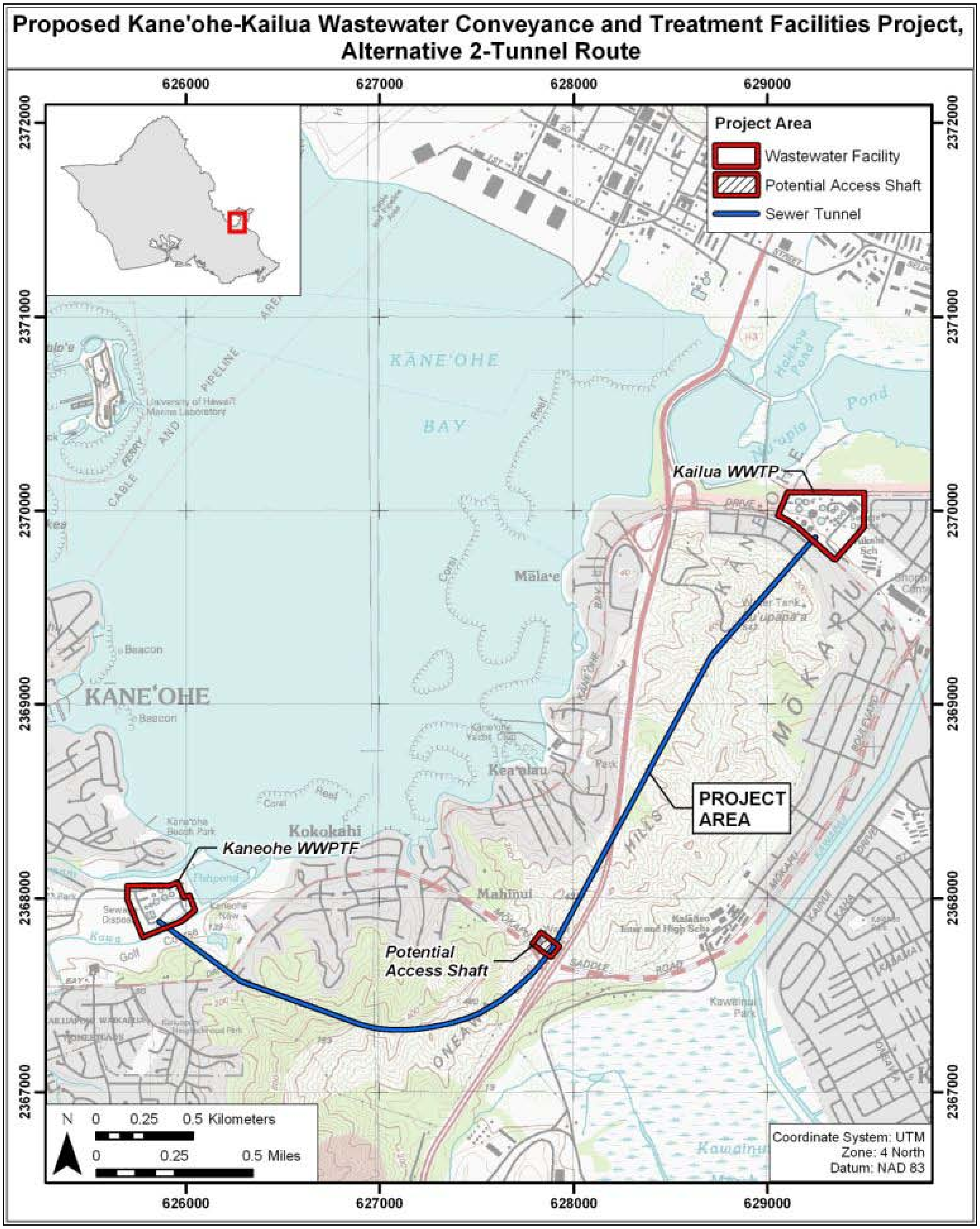

Figure 2. Portion of the 1998 Honolulu USGS 7.5 minute topographic quadrangle showing the Project area

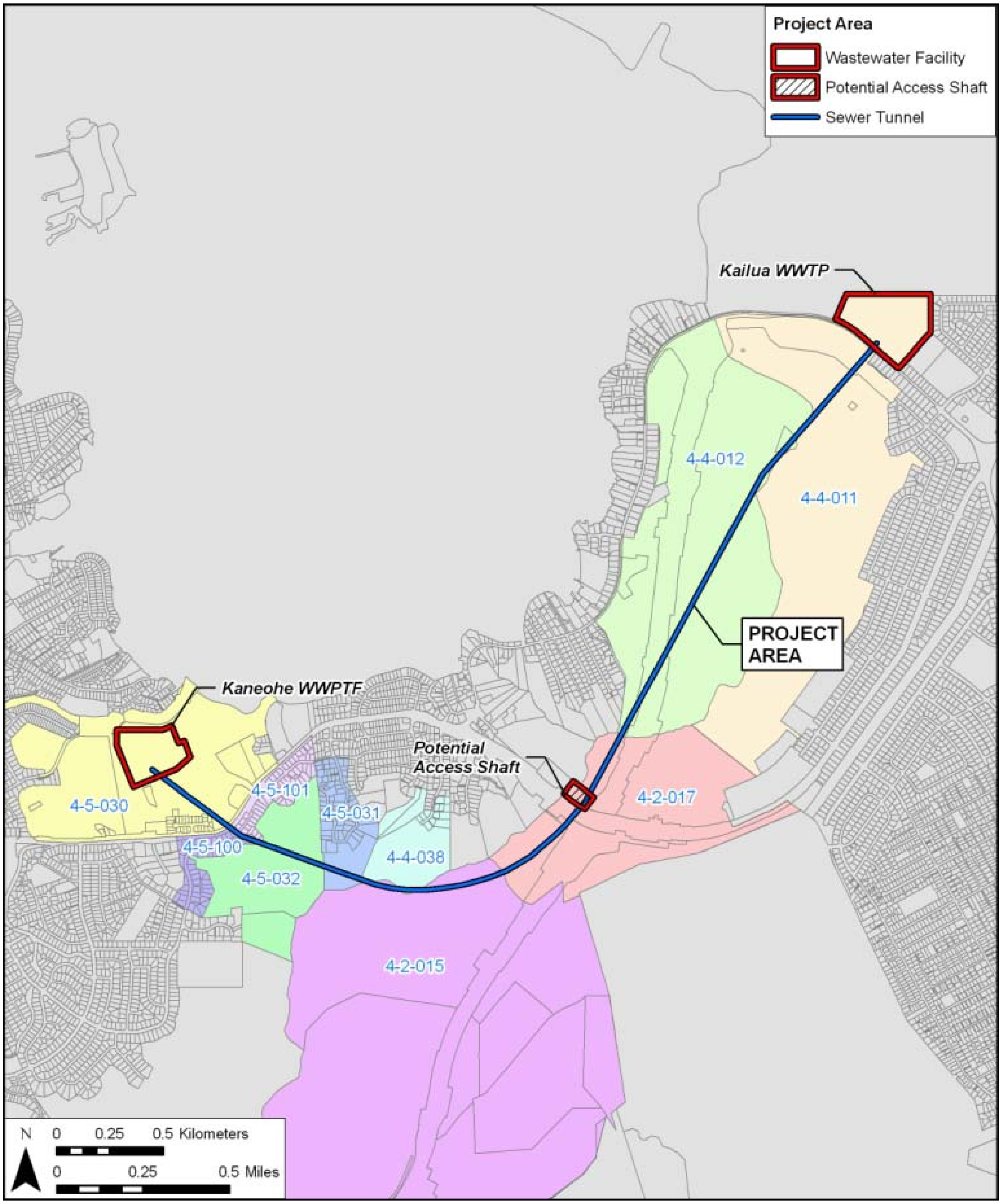

Figure 3. Tax Map Key (TMK): [1] 4-2-15, 4-2-17, 4-4-011, 4-4-012, 4-4-038, 4-5-030, 4-5-31, 4-5-032, 4-5-100, 4-5-101 showing the Project area (Hawai‘i Tax Map Key Service 2010)

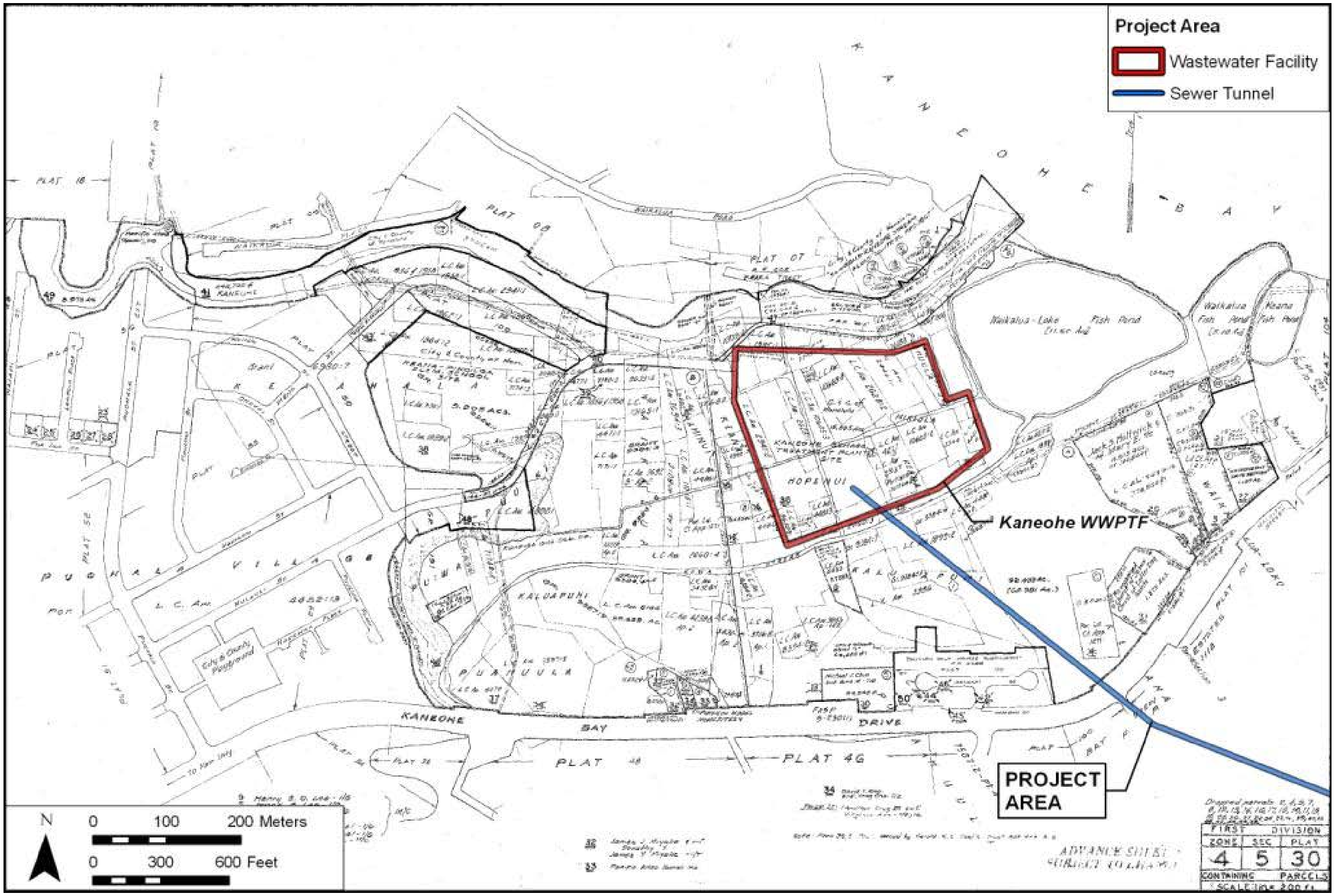

Figure 4. TMK: [1] 4-5-030 showing the Project area near the Kāneʻohe WWPTF (Hawaiʻi Tax Map Key Service 2010)

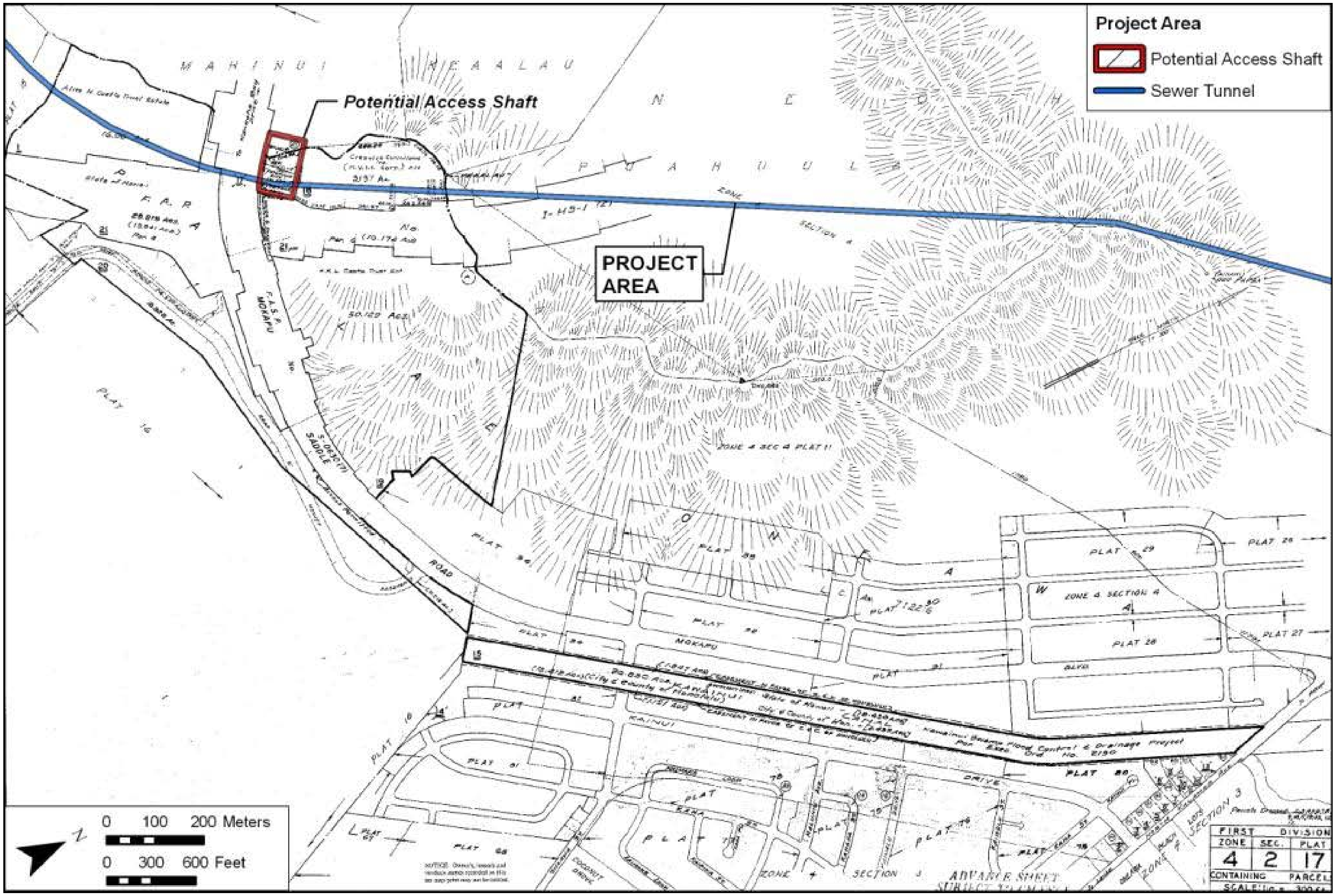

Figure 5. TMK: [1] 4-2-017 showing the Project area near the potential access shaft (Hawai‘i Tax Map Key Service 2010)

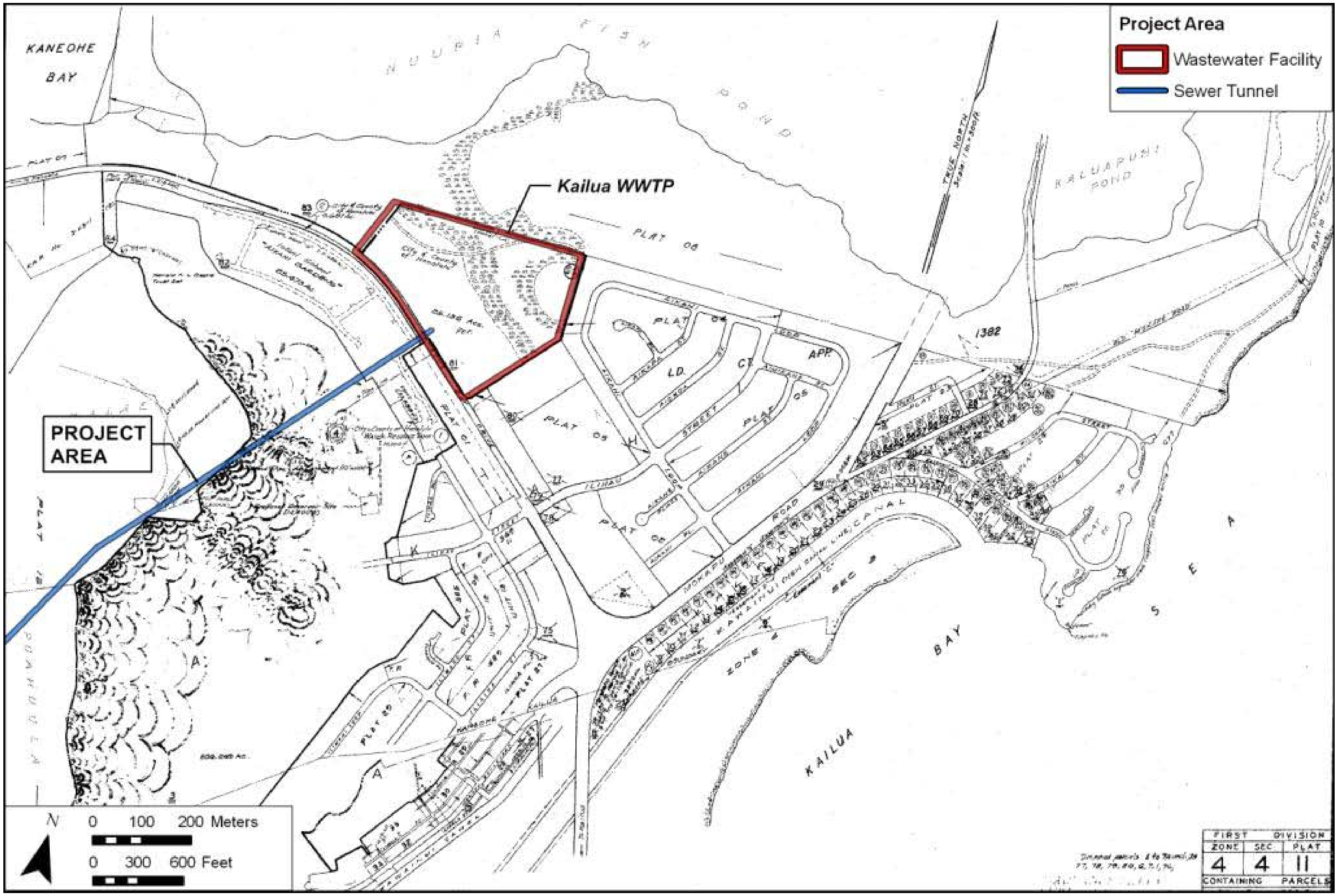

Figure 6. TMK: [1] 4-4-011 showing the Project area near the Kailua WWTP (Hawai‘i Tax Map Key Service 2010)

1.2 Document Purpose

The Project requires compliance with the State of Hawaiʻi environmental review process (Hawaiʻi Revised Statutes [HRS] Chapter 343), which requires consideration of a proposed Project's effect on cultural practices. CSH is conducting this CIA at the request of Wilson Okamoto Corporation. Through document research and ongoing cultural consultation efforts, this report provides information pertinent to the assessment of the proposed Project's impacts to cultural practices and resources (per the *Office of Environmental Quality Control's Guidelines for Assessing Cultural Impacts*), which may include Traditional Cultural Properties (TCPs) of ongoing cultural significance that may be eligible for inclusion on the State Register of Historic Places, in accordance with Hawaiʻi State Historic Preservation Statute (Chapter 6E) guidelines for significance criteria in Hawaiʻi Administrative Rules (HAR) §13-275 under Criterion E, which states to be significant an historic property shall:

> Have an important value to the Native Hawaiian people or to another ethnic group of the state due to associations with cultural practices once carried out, or still carried out, at the property or due to associations with traditional beliefs, events or oral accounts—these associations being important to the group's history and cultural identity.

The document is intended to support the Project's environmental review and may also serve to support the Project's historic preservation review under HRS Chapter 6E and HAR Chapter 13-275.

1.3 Scope of Work

The scope of work for this CIA includes:

1. Examination of cultural and historical resources, including Land Commission documents, historic maps, and previous research reports, with the specific purpose of identifying traditional Hawaiian activities including gathering of plant, animal, and other resources or agricultural pursuits as may be indicated in the historic record.
2. Review of previous archaeological work at and near the subject parcel that may be relevant to reconstructions of traditional land use activities; and to the identification and description of cultural resources, practices, and beliefs associated with the parcel.
3. Consultation and interviews with knowledgeable parties regarding cultural and natural resources and practices at or near the parcel; present and past uses of the parcel; and/or other practices, uses, or traditions associated with the parcel and environs.
4. Preparation of a report that summarizes the results of these research activities and provides recommendations based on findings.

1.4 Environmental Setting

1.4.1 Natural Setting

Kāneʻohe is a relatively large *ahupuaʻa* (land division usually extending from the uplands to the sea) that extends from the peaks of the Koʻolau Mountains to the coast of Kāneʻohe Bay and includes the leeward portion of Mōkapu Peninsula. The Project area traverses the southeastern edge of Kāneʻohe Bay in Kāneʻohe Ahupuaʻa. The western portion of the Project area begins on the coastal plain immediately *mauka* of Waikalua Loko Fishpond between Kāneʻohe and Kawa Streams. The sewer tunnel alignment extends toward Oneawa Hills and then curves east to the proposed location of the access shaft just *makai* (seaward) of Mōkapu Saddle Road at its intersection with Interstate H-3. The sewer tunnel alignment continues to run beneath Oneawa Hills until it reaches the low-lying lands near Nuʻupia Fishpond between Kāneʻohe Bay and Kailua Bay just prior to the eastern section of Mōkapu Peninsula.

1.4.2 Soil and Vegetation

Much of the proposed Project-related excavations would occur at depths greater than 35 feet (10.7 meters), which would most likely be within limestone or basalt bedrock. Soils in the portions of the Project area where near-surface excavations would occur include the following soils: Hanalei Silty Clay (HnA) within the vicinity of Kaneohe WWPT; Alaeloa Silty Clay (ALF) within the vicinity of the intermediate tunnel shaft; and Kokokahi Clay (KtC), Keaau Clay (KmbA); Mamala Stony Silty Clay Loam (MnC), and Jaucus Sand (JcC) within the vicinity of Kailua WWTP (Foote et al. 1972) (Figure 7). The Hanalei Series are poorly drained soils developed in alluvium from igneous rock, with the following natural vegetation: California grass, *honohono* (dayflower), sensitive plant, and Java plum (Foote et al. 1972:38–39). Soils of the Alaeloa Series are well drained and formed in material weathered from igneous rock and contain the following common vegetation: guava, Java plum, christmasberry, Japanese tea, sensitive plant, Hilo grass, and *honohono* (Foote et al. 1972:26). The Kokokahi Series are moderately well-drained soils on slopes and alluvial fans with the following vegetation: *kiawe* (Algaroba tree), klu, *koa haole*, Bermuda grass, and bristly foxtail (Foote et al. 1972:73). The Keaau Series are poorly drained soils formed in alluvium over reef limestone or coral sand with the following natural vegetation: *kiawe*, Bermuda grass, bristly foxtail, and finger grass (Foote et al. 1972:64–65). The Mamala Series are well-drained soils formed from alluvium deposited over coral limestone and calcareous sand with *kiawe*, *koa haole*, klu, bristly foxtail, and finger grass (Foote et al. 1972:93). Finally, the Jaucas Series consists of excessively drained calcareous soils on coastal plains developed in sand from coral and seashells with the following vegetation: *kiawe*, *koa haole*, bristly foxtail, Bermuda grass, finger grass, and Australian saltbush (Foote et al. 1972:48).

1.4.3 Built Environment

Development within the Project area consists of municipal wastewater infrastructures, including wastewater treatment plant structures and sewer pump stations. The subsurface portion of the Project area is generally located beneath Oneawa Hills.

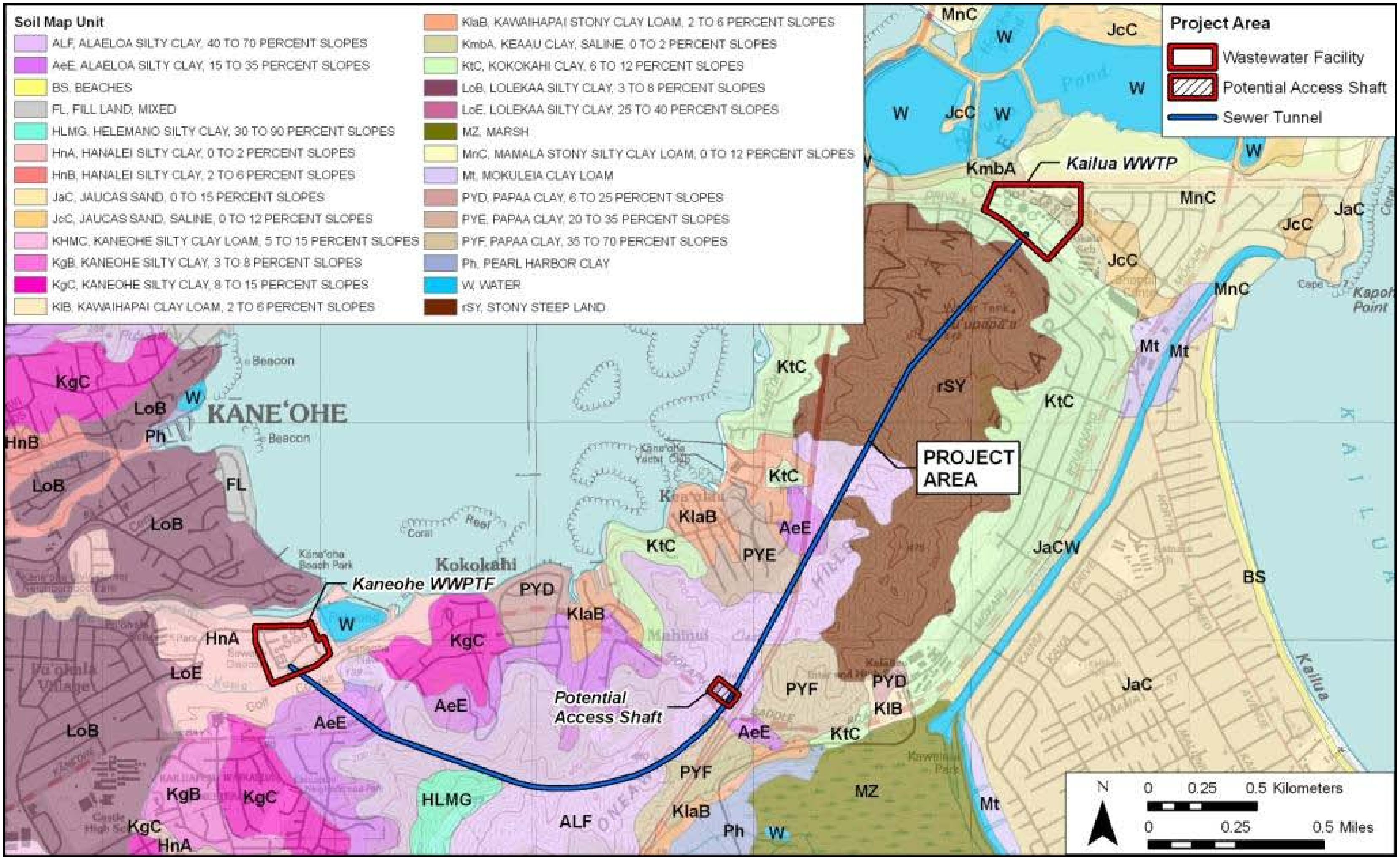

Figure 7. Portion of 1998 Honolulu USGS 7.5-minute series topographic quadrangle showing the Project area with soil overlay (Foote el al. 1972)

Section 2 Methods

2.1 Archival Research

Historical documents, maps and existing archaeological information pertaining to Kāne‘ohe were researched at the CSH library and other archives including the University of Hawai‘i at Mānoa’s Hamilton Library, the State Historic Preservation Division (SHPD) library, the Hawai‘i State Archives, the State Land Survey Division, and the archives of the Bishop Museum. Previous archaeological reports for the area were reviewed, as were historic maps and photographs and primary and secondary historical sources. Information on Land Commission Awards (LCAs) was accessed through Waihona ‘Aina Corporation’s Māhele Data Base (www.waihona.com) as well as a selection of CSH library references. Research for the Cultural and Historical Background section centered on the following cultural and historic resources, practices, and beliefs: religious and ceremonial knowledge and practices; traditional subsistence land use and settlement patterns; gathering practices and agricultural pursuits; *wahi pana* (storied places) and associated *mo‘olelo* (stories, oral traditions), *mele* (songs), *oli* (chants), and *‘ōlelo no‘eau* (proverbs); and historic land transformation, development, and population changes (see Scope of Work above).

2.2 Community Consultation

2.2.1 Sampling and Recruitment

A combination of qualitative methods, including purposive, snowball, and expert (or judgment) sampling, were used to identify and invite potential participants to the study. These methods are used for intensive case studies, such as CIAs, to recruit people that are hard to identify, or are members of elite groups (Bernard 2006:190). Our purpose is not to establish a representative or random sample. It is to “identify specific groups of people who either possess characteristics or live in circumstances relevant to the social phenomenon being studied….This approach to sampling allows the researcher deliberately to include a wide range of types of informants and also to select key informants with access to important sources of knowledge” (Mays and Pope 1995:110).

We began with purposive sampling informed by referrals from known specialists and relevant agencies. For example, we contacted the SHPD, Office of Hawaiian Affairs (OHA), O‘ahu Island Burial Council (OIBC), and community and cultural organizations in Kāne‘ohe for their brief response/review of the Project and to identify potentially knowledgeable individuals with cultural expertise and/or knowledge of the Project area and vicinity, cultural and lineal descendants of Kāne‘ohe, and other appropriate community representatives and members. Based on their in-depth knowledge and experiences, these key respondents then referred CSH to additional potential participants who were added to the pool of invited participants. This is snowball sampling, a chain referral method that entails asking a few key individuals (including agency and organization representatives) to provide their comments and referrals to other locally recognized experts or stakeholders who would be likely candidates for the study (Bernard 2006:192). CSH also employs expert or judgment sampling which involves assembling a group of people with recognized experience and expertise in a specific area (Bernard 2006:189–191). CSH maintains a database that draws on over two decades of established relationships with community consultants: cultural practitioners and specialists, community representatives and cultural and lineal descendants. The names of new potential contacts were also provided by colleagues at CSH and from the researchers' familiarity with people who live in or around the study area. Researchers often attend public forums (e.g., Neighborhood Board, Burial Council and Civic Club meetings) in (or near) the study area to scope for participants. Please refer to Table 2, Section 5, for a complete list of individuals and organizations contacted for this CIA.

CSH focuses on obtaining in-depth information with a high level of validity from a targeted group of relevant stakeholders and local experts. Our qualitative methods do not aim to survey an entire population or subgroup. A depth of understanding about complex issues cannot be gained through comprehensive surveying. Our qualitative methodologies do not include quantitative (statistical) analyses, yet they are recognized as rigorous and thorough. Bernard (2006:25) describes the qualitative methods as "a kind of measurement, an integral part of the complex whole that comprises scientific research." Depending on the size and complexity of the project, CSH reports include in-depth contributions from about one-third of all participating respondents. Typically this means three to twelve interviews.

2.2.2 Informed Consent Protocol

An informed consent process was conducted as follows: (1) before beginning the interview the CSH researcher explained to the participant how the consent process works, the Project purpose, the intent of the study and how his/her information will be used; (2) the researcher gave him/her a copy of the Authorization and Release Form to read and sign (Appendix C); (3) if the person agreed to participate by way of signing the consent form or providing oral consent, the researcher started the interview; (4) the interviewee received a copy of the Authorization and Release Form for his/her records, while the original is stored at CSH; (5) after the interview was summarized at CSH (and possibly transcribed in full), the study participant was afforded an opportunity to review the interview notes (or transcription) and summary and to make any corrections, deletions or additions to the substance of their testimony/oral history interview; this was accomplished either via phone, post or email or through a follow-up visit with the participant; (6) the participant received the final approved interview and any photographs taken for the study for record. If the participant was interested in receiving a copy of the full transcript of the interview (if there is one as not all interviews are audio-recorded and transcribed), a copy was provided. Participants were also given information on how to view the report on the OEQC website and offered a hardcopy of the report once the report is a public document.

2.2.3 Interview Techniques

To assist in discussion of natural and cultural resources and cultural practices specific to the study area, CSH initiated semi-structured interviews (as described by Bernard 2006) asking questions from the following broad categories: gathering practices, *mauka* and *makai* resources, burials, trails, historic properties, and *wahi pana*. The interview protocol is tailored to the specific natural and cultural features of the landscape in the study area identified through archival research and community consultation. In this study, for example, fishing, recreational uses of the ocean, and agriculture were emphasized over other categories less salient to Project participants. These interviews and oral histories supplement and provide depth to consultations from government agencies and community organizations that may provide brief responses, reviews and/or referrals gathered via phone, email and occasionally face-to-face commentary.

2.2.3.1 In-depth Interviews and Oral Histories

Interviews with *kūpuna* (elder) and *kamaʻāina* (Native-born) were conducted initially at a place of the study participant's choosing (usually at the participant's home or at a public meeting place) and/or—whenever feasible—during site visits to the Project area. Generally, CSH's preference is to interview a participant individually or in small groups (two–four); occasionally participants are interviewed in focus groups (six–eight). Following the consent protocol outlined above, interviews may be recorded on tape and in handwritten notes, and the participant photographed. The interview typically lasts one to four hours, and records the—who, what, when and where of the interview. In addition to questions outlined above, the interviewee is asked to provide biographical information (e.g., connection to the study area, genealogy, professional and volunteer affiliations, etc.).

2.3 Compensation and Contributions to Community

Many individuals and communities have generously worked with CSH over the years to identify and document the rich natural and cultural resources of these islands for cultural impact, ethno-historical and, more recently, TCP studies. CSH makes every effort to provide some form of compensation to individuals and communities who contribute to cultural studies. This is done in a variety of ways: individual interview participants are compensated for their time in the form of a small honorarium and/or other *makana* (gift); community organization representatives (who may not be allowed to receive a gift) are asked if they would like a donation to a Hawaiian charter school or nonprofit of their choice to be made anonymously or in the name of the individual or organization participating in the study; contributors are provided their transcripts, interview summaries, photographs and—when possible—a copy of the CIA report; CSH is working to identify a public repository for all cultural studies that will allow easy access to current and past reports; CSH staff do volunteer work for community initiatives that serve to preserve and protect historic and cultural resources (for example in, Lānaʻi and Kahoʻolawe). Generally our goal is to provide educational opportunities to students through internships, share our knowledge of historic preservation and cultural resources and the State and Federal laws that guide the historic preservation process, and through involvement in an ongoing working group of public and private stakeholders collaborating to improve and strengthen the Chapter 343 environmental review process.

Section 3 Cultural and Historical Background

This section draws from archaeology, ethnography, and an archive of historic documents to present a portrait of Hawaiian culture and history as it relates to the specific Project area. Focusing in on geographic and temporal scales, this section first traces the exploration of the Pacific Ocean and the subsequent discovery and settlement of the Hawaiian archipelago, the opening and closing of a voyaging corridor between Hawaiʻi and Tahiti, and later cultural changes and distinctive Hawaiian innovations that are reflected in the archaeological record, including expansion into marginal environments, exponential population growth, intensification of production, increased social stratification, and territorial division of land. This broad overview leads to an approximate chronological history of the *ahupuaʻa* of the Project area, including the earliest known settlement and subsistence patterns, a compilation of *wahi pana* and associated *moʻolelo*, successions of chiefly rule, the introduction of private property, and land-use changes.

3.1 Discovery and Settlement of the Hawaiian Islands

By 10,000 years ago, humans had migrated to occupy nearly all the habitable land on the planet. Aside from crossing a series of short water gaps to reach Australia and New Guinea, they had reached it all by walking. The remaining unexplored region was the vast Pacific Ocean. Approximately 4,500 years ago, coastal dwellers of southeast China began a wave of migration through the closely-spaced, inter-visible islands of Southeast Asia. Advances in sailing strategies, canoe technology, and navigation techniques enabled their descendants to sail past the familiar insular waters a millennium later. These precocious seafarers systematically explored the remote, uninhabited regions of the Pacific Ocean to the east, as well as the Indian Ocean to the west. This led to the eventual discovery and colonization of virtually every habitable island in the Pacific Ocean, as well as coastal trading along the Indian sub-continent and settlement as far west as Madagascar (Howe 2007; Irwin 2007).

The ancient wayfinders most likely employed an expansionary strategy of first staging a series of exploratory probes to find likely islands, followed by returns to the homeland, and then launching colonizing expeditions (Irwin 1992). To do so, they sailed their double-hulled voyaging canoes eastward against the direction of the dominant trade winds by waiting for westerly wind shifts. After mentally mapping the positions of newly discovered islands in terms of celestial referents, they returned to their homelands to share the sailing directions for future voyages of colonization (Finney 1996). As most of the Pacific Islands are volcanic in origin, the exploratory seafarers, also horticulturalists, necessarily transported a landscape of plants. They brought with them taro, yams, breadfruit, bananas, and coconuts, as well as domesticated pigs, dogs, and chickens, and, possibly with intention, rats (Irwin 2007; Kirch 2000).

Later voyagers discovered and settled the distant archipelagoes of western Polynesia (e.g., Samoa, Tonga, and Fiji), the northwestern archipelagoes of Micronesia (e.g., Marshall Islands and Caroline Islands), and eastern Polynesia (e.g. Tahiti and Marquesas), and from there settled the widely-separated archipelagoes of Hawaiʻi and Aotearoa as well as the solitary island of Rapa Nui (Irwin 2007; Kirch 2000). Finney (2007:145) suggests that a waxing and waning rhythm of voyaging characterized the large, high-island archipelagoes of eastern Polynesia: "a flurry of back and forth sailings as the islands are being discovered, settled and supplied; then some continued long-range travel for personal, religious or other reasons; and then by a contraction of voyaging as populations grew and rival chiefdoms fought over land and power."

Archeological excavations, linguistic reconstructions, and genetic studies suggest that the initial settlement of Hawaiʻi came from eastern Polynesia as early as A.D. 300–600 (Kirch 2000:291) or as late as A.D. 700–800 (Athens et al. 2002). *Moʻolelo* link Hawaiʻi to Kahiki—the generic word for the ancestral homeland of Hawaiians, not a specific island—through accounts of the discovery of certain Hawaiian islands and subsequent inter-archipelago return trips (Beckwith 1970). The first colonizers of Hawaiʻi from within the region of Kahiki were probably from the Marquesas Islands (Kirch 2000:291). The archaeological record suggests that early Hawaiians formed settlements of hamlets along the coasts, interred the dead, ate domesticated pigs, dogs, and chickens, and began to clear tracts of forest between A.D. 600–1100 (Kirch 2000:293).

The early settlers of the Hawaiian archipelago would have been especially attracted to windward Oʻahu with its coral reefs, bays, and sheltered inlets for fishing, dense basalt dikes for the production of stone adzes and other tools, and amphitheatre-headed valleys and broad alluvial floodplains that contained fertile soils, numerous permanently flowing streams, and abundant rainfall for the cultivation of crops (Kirch 1985:69). The earliest known occupation sites on Oʻahu, in fact, are found in this region. Kirch's (1985:69–80) synthesis of these archaeological sites provides a glimpse into the life of these early settlers of Hawaiʻi, who may have resided close to the Project area. One site in particular—the Bellows Beach sand dune occupation site in Waimānalo—suggests settlement as early as A.D. 300–400 (Kirch 1985:71). While these radiocarbon dates have been much disputed, the cultural layers within the sand dunes are still considered among the oldest in Hawaiʻi (e.g. Dye 2000). Archaeological excavation data from this site indicate that the settlers and their descendants, like their east Polynesian ancestors, lived in pole-and-thatch dwellings near the coast in a small hamlet, interred the dead beneath these structures, cooked in small hearths (Figure 8), manufactured tools, such as shell coconut graters (Figure 9), stone adzes (Figure 10), and bone and shell fishhooks (Figure 11), and supported themselves by cultivating inland crops, raising domesticated animals, hunting seabirds on offshore islets, fishing, and gathering shellfish (Kirch 1985:71–74). As the residents of Waimānalo adapted to local conditions, they invented distinctive Hawaiian artifacts, including two-piece fishhooks and the *lei niho palaoa* (*lei* of rock oyster shell), which, in addition to other ornaments interred with individuals, suggests a degree of social stratification (Kirch 1985: 1–74). Hawaiians also cared for the dead with a variety of *ilina* (burials, graves) depending on the social status of the deceased, including cremation burials, burial caves, burials in the sand and earth, burials directly underneath house floors, burials in the platforms of *heiau* (temples), and burials marked on the surface by stone terraces, mounds, platforms, and other monuments (Kirch 1985:238–242).

New fishhook styles discovered in Hawaiian archaeological sites and Tahitian words entering into the Hawaiian language suggest contact with Tahiti around A.D. 1200 (Kirch 2000:291). In addition, numerous *moʻolelo* chronicle the era of two-way voyaging between the archipelagoes of Tahiti and Hawaiʻi by detailing the feats of specific navigators (Cachola-Abad 1993). The Hawaiʻi-Tahiti voyaging corridor eventually ceased as Hawaiians and Tahitians began to focus more on local initiatives, such as building, maintaining, and deploying fleets of war canoes rather than guiding them on overseas adventures (Finney 2007:145). According to Fornander’s (1878:168–169) synthesis of *mo‘olelo*, the *ali‘i* (chief) La‘amaikahiki closed the era of voyaging between Tahiti and Hawai‘i when he returned to his ancestral homeland 21 generations before the 1870s. With an average of 20 years between generations, that places the cessation of Hawaiian long-distance voyaging at about A.D. 1450 (Fornander 1878:168–169).

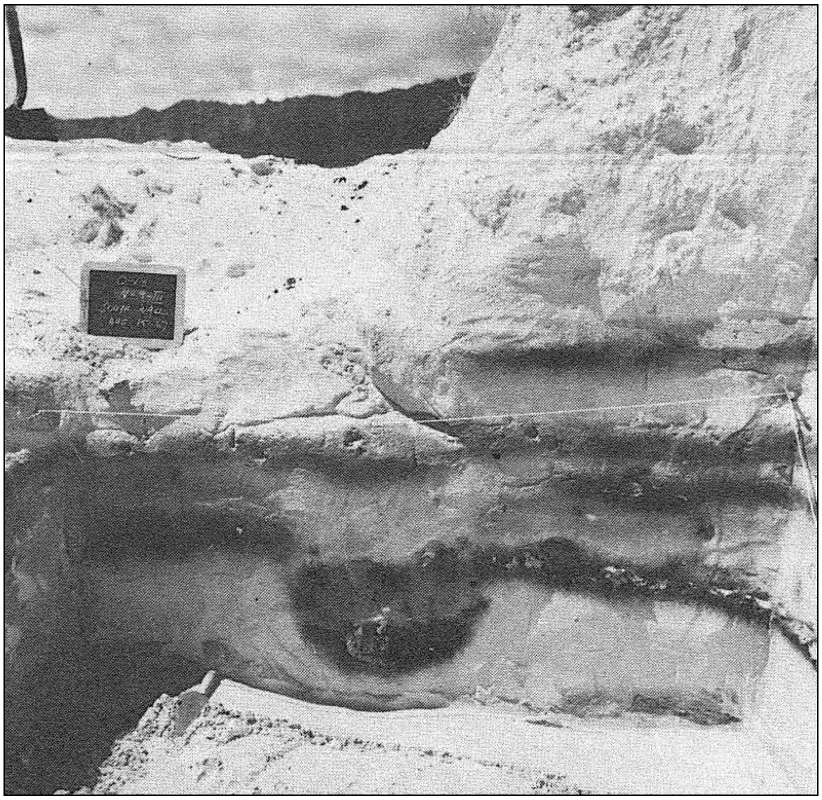

Figure 8. A hearth cuts through the early occupation levels in the Bellows Beach sand dune site, which are marked by black midden deposits and separated by layers of sand (Kirch 1985:71)

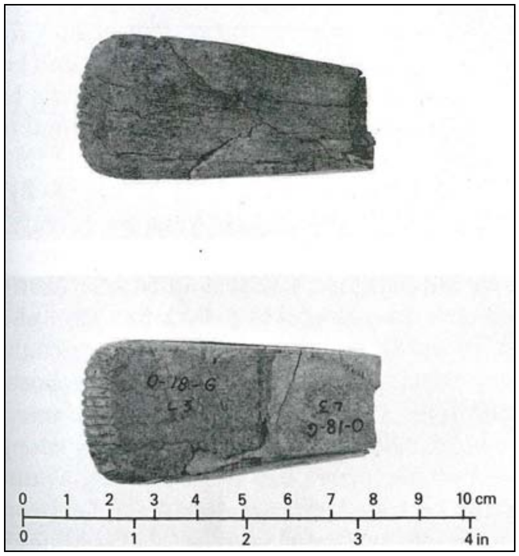

Figure 9. Front and back views of a cone-shell coconut grater from the Bellows Beach sand dune site (Kirch 1985:73)

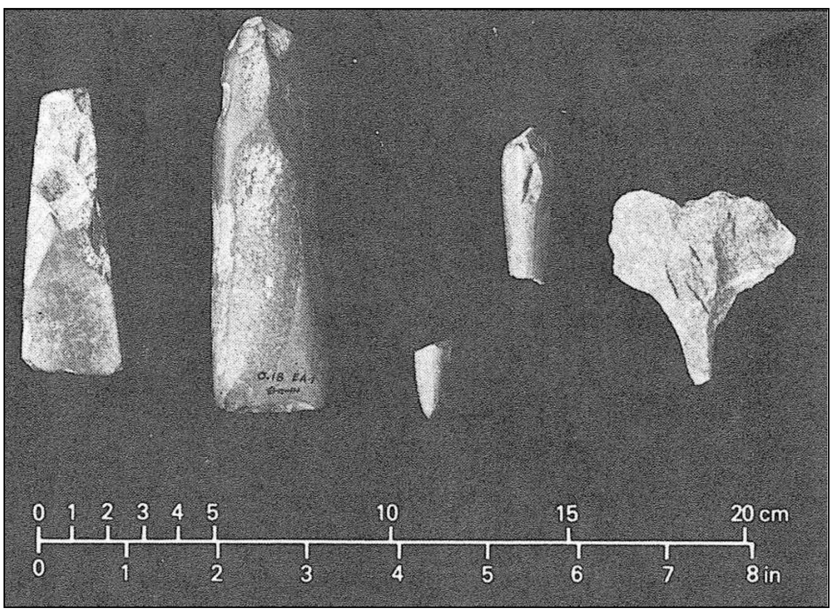

Figure 10. Stone artifacts from the Bellows Beach sand dune site; (from left to right) adzes, chisel fragments, and an awl (Kirch 1985:73)

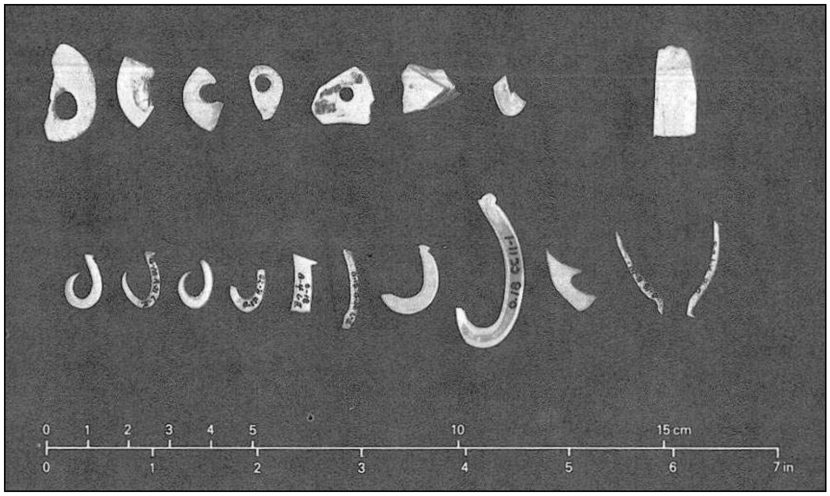

Figure 11. Fishing gear from the Bellows Beach sand dune site; (top row) unfinished fishhooks of bone and shell, and (bottom row) one-piece fishhooks and a segments of a two-piece fishhook (at far right) (Kirch 1985:73)

3.2 Expansion and Intensification

The archaeological record suggests that Hawaiians experienced exponential population growth, intensification of production, and increased social stratification around A.D. 1100–1650. Hawaiians converted valley floors and hillsides to *loʻi* (terraced fields) with *ʻauwai* (ditches) that diverted stream water to irrigate *kalo* (taro) and other crops in flooded pond fields, developed dryland field systems for the cultivation of *ʻuala* (sweet potato) and other crops, and constructed stone-walled *loko iʻa* (fishponds) on shallow reef flats to grow and harvest fish (Kirch 2000:293–295). By A.D. 1600, the population, which had burgeoned to at least several hundred thousand people, expanded from the fertile windward regions into the most arid and marginal regions of the archipelago—the leeward valleys and coasts (Kirch 2007). This agricultural and aquacultural intensification supported emerging classes of *aliʻi* and *makaʻāinana* (commoners), whose labor created enduring *heiau* and other monuments that survive in the archaeological record (Kirch 2000:295–296).

The original settlers and their descendants had likely organized themselves into kin-based social groups. The necessity of defining territorial boundaries increased as the population rapidly grew, the amount of available land diminished, voyaging spheres contracted, and the society became more differentiated, hierarchical, and competitive (Kirch 1985:306). The original lineage territories and associated chiefdoms were most likely *mokuʻāina*, or *moku*, (districts) that were sequentially divided (Ladefoged and Graves 2006). Between A.D. 1400–1500, Hawaiians developed a system of land tenure that centered on the *ahupuaʻa*, a territorial unit that typically extended from the peaks of the mountains down to the sea, encompassing the entire ecology of an island and incorporating its main resource zones, including interior uplands and mountains, coastal lowlands, and fringing reefs (Kirch 2000:296). The *makaʻāinana* remained on the land they cultivated, but *aliʻi* now governed this *ahupuaʻa* pattern of territorial units. These *ahupuaʻa* territories changed through time; the regions in a *moku* with greater predictability of resources were most likely settled first and defined according to topographic features, and later divided into separate communities if increases in production could support larger populations (Ladefoged and Graves 2006).

3.3 Kāne‘ohe Ahupua‘a

Based on the distribution of sites into the most arid and marginal lands, virtually all of O‘ahu was territorially claimed and possibly occupied by A.D. 1650 (Kirch 1992:15). O‘ahu was divided into six *moku*—Kona, ‘Ewa, Wai‘anae, Waialua, Ko‘olauloa, and Ko‘olaupoko—that were further divided into 86 *ahupua‘a* (Kame‘eleihiwa 1992:330) (Figure 12). These lands, in turn, were further partitioned into *‘ili* (land sections within an *ahupua‘a*). The Māhele of 1848 introduced private land ownership laws, but modern maps and land boundaries still generally follow the ancient system of land tenure and division.

The Project area traverses the *makai* section of Kāne‘ohe Ahupua‘a between Kāne‘ohe Bay and Kailua Bay in the central portion of Ko‘olaupoko Moku on the island of O‘ahu (Figure 13). Kāne‘ohe Ahupua‘a contains numerous archaeological sites indicative of ancient habitation and subsistence and other *wahi pana* (Figure 14), several of which are located on the *‘ili* of Waikalua, Keana, Mahinui, Kalāheo, Pa‘alae, Pū‘ahu‘ula, Māla‘e, and ‘Aikahi (Lyons 1876; Wall 1914) above the subsurface Project corridor along the Kāne‘ohe Bay shoreline (Figure 15 and Figure 16).

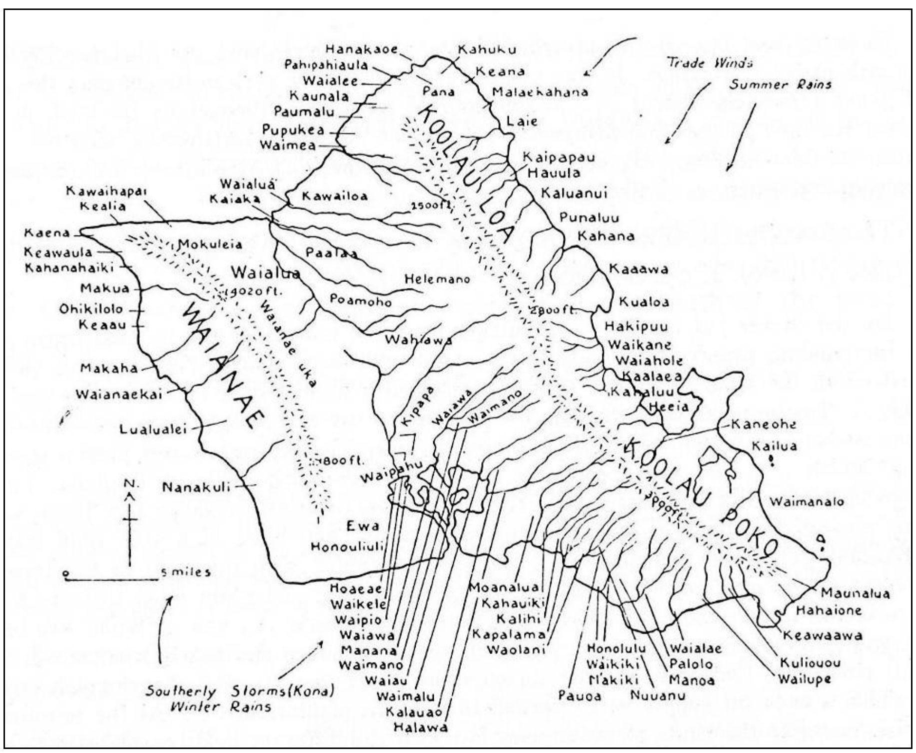

Figure 12. *Moku* and *ahupua‘a* of O‘ahu (Handy 1940:75)

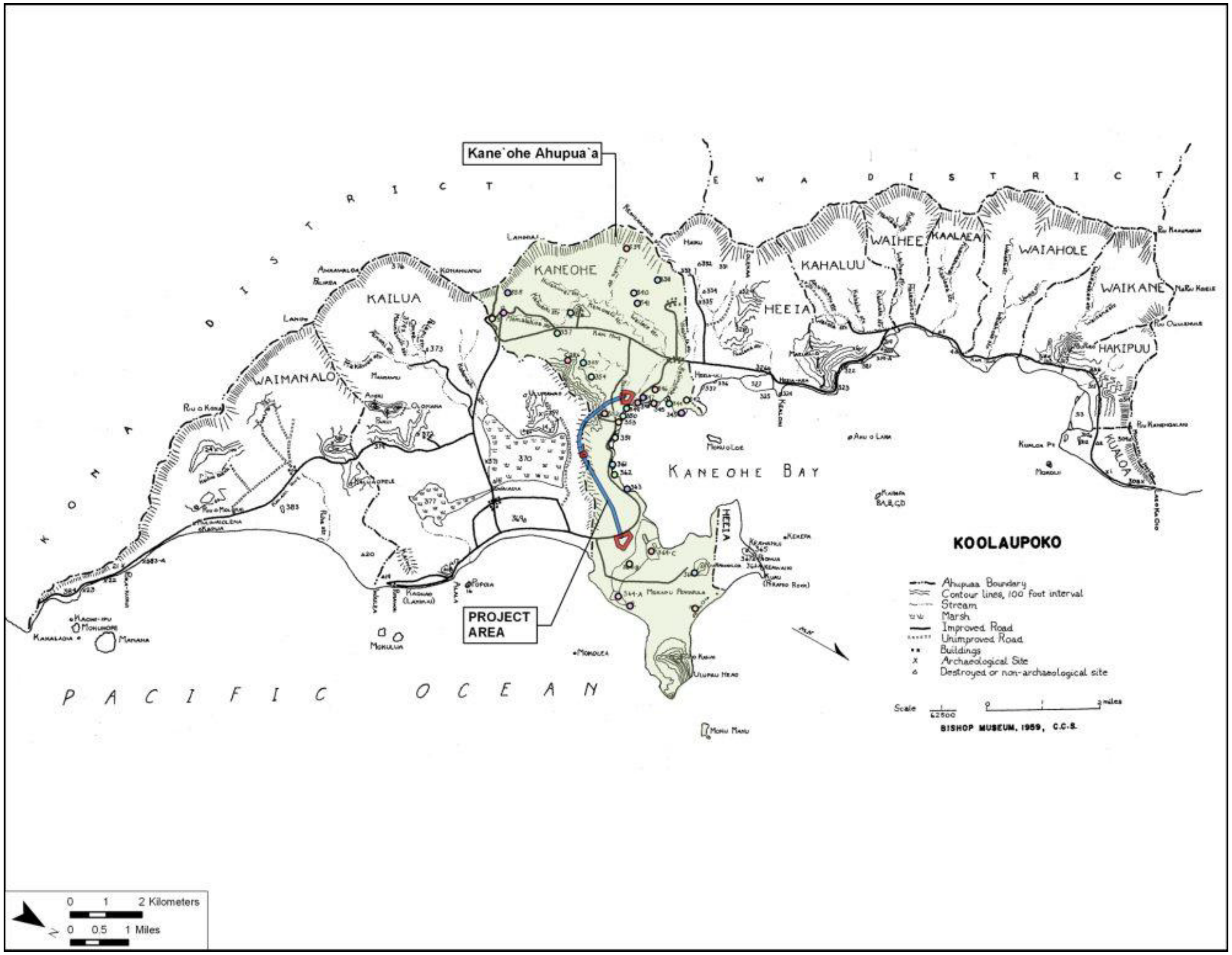

Figure 13. The *moku* of Ko‘olaupoko, showing the *ahupua‘a* of He‘eia and the Project area (Sterling and Summers 1978)

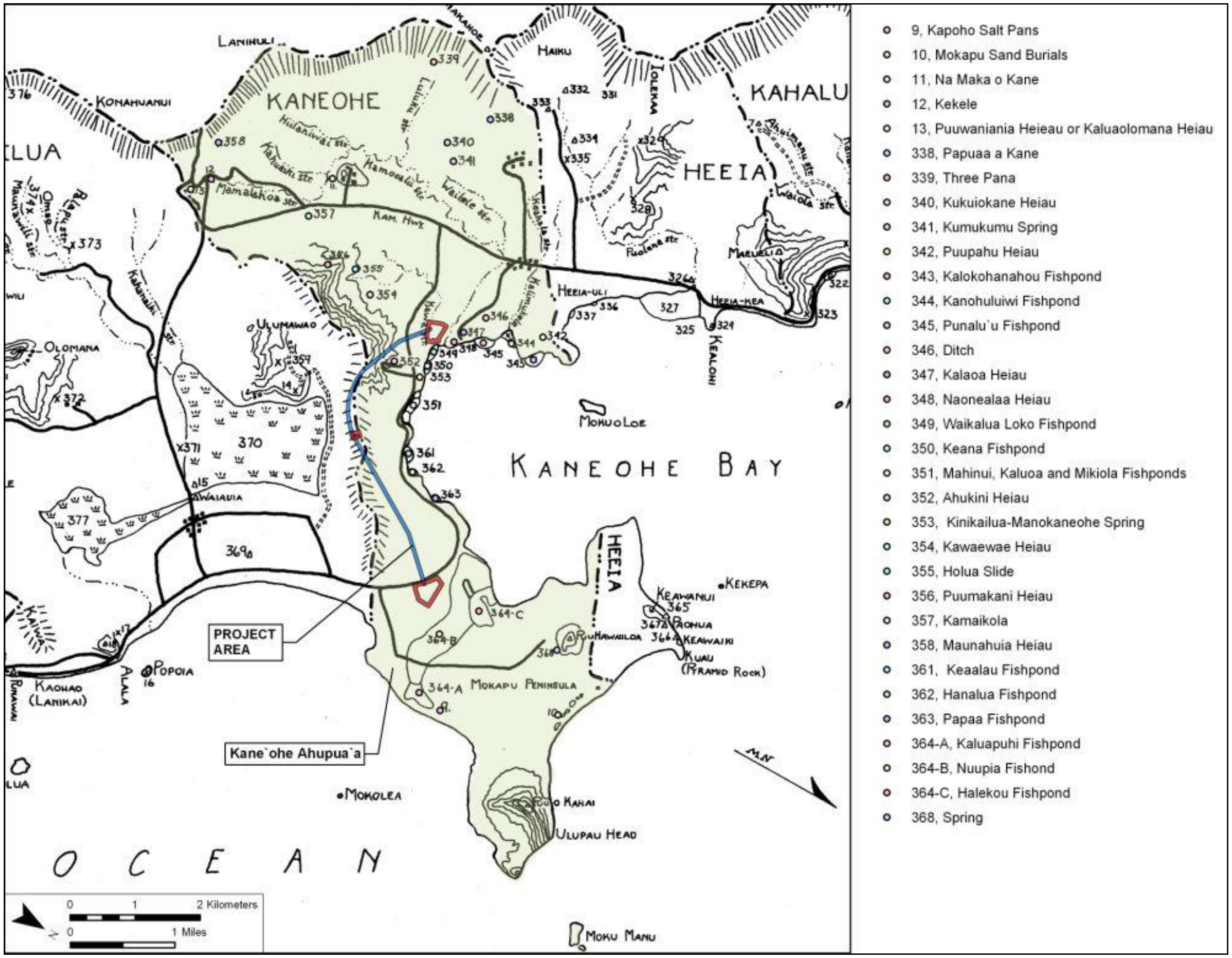

Figure 14. *Wahi pana* in the ahupua‘a of Kāne‘ohe (Sterling and Summers 1978); sites listed are from McAllister (1933)

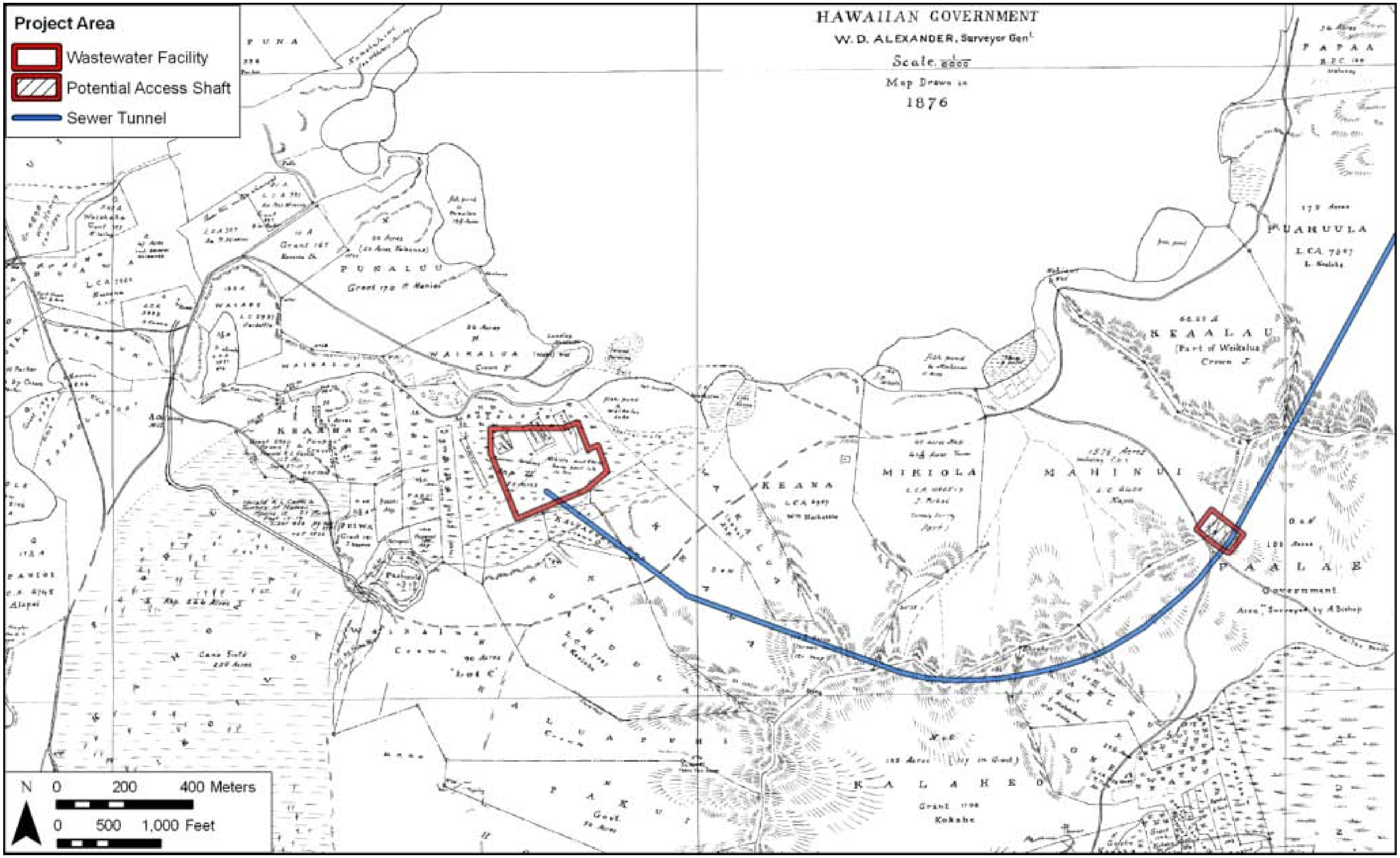

Figure 15. Map of Kāneʻohe and West Kailua (Lyons 1876) showing the *ʻili* along the western portion of the Project corridor

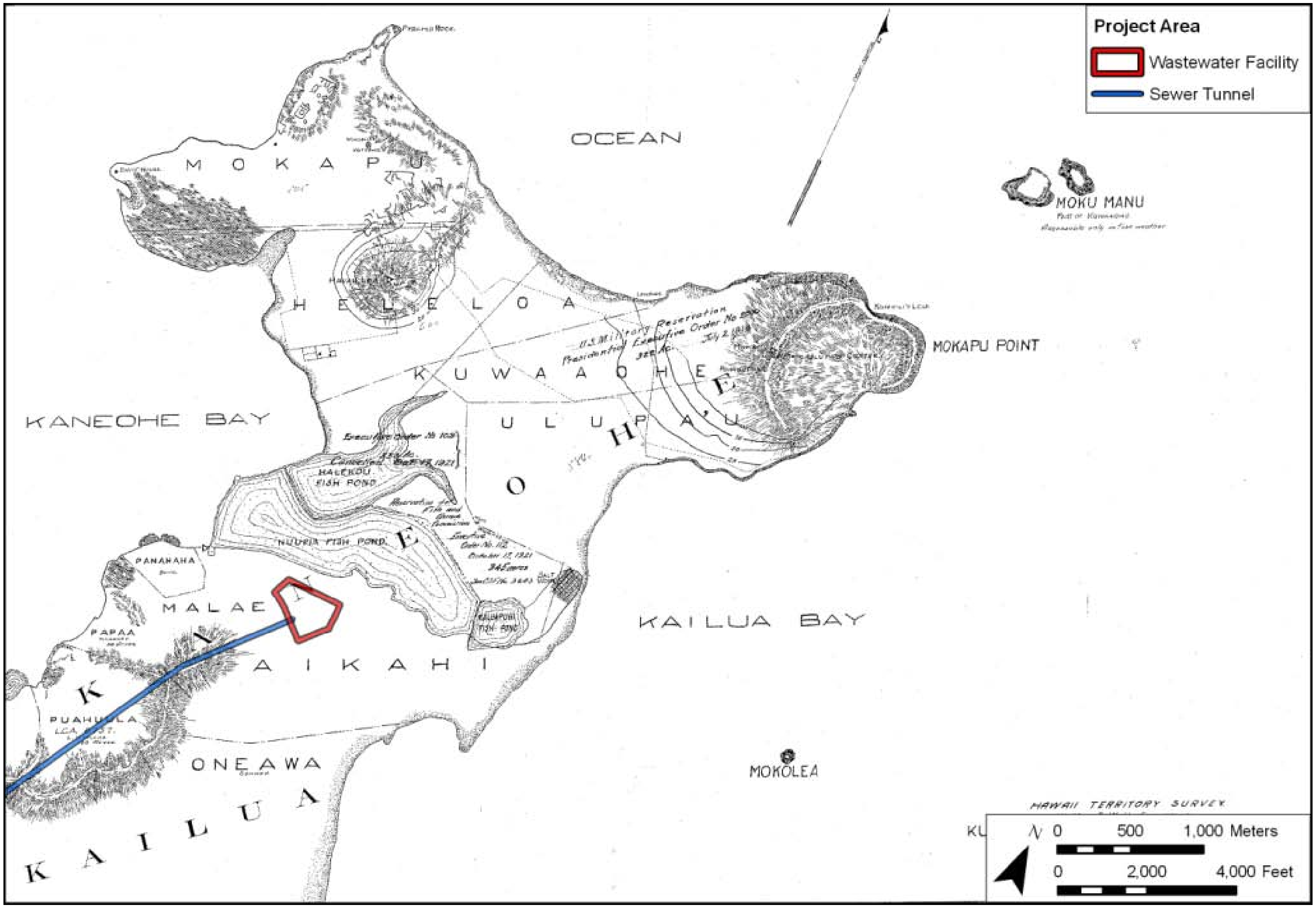

Figure 16. Map of Kuwaaohe and Halekou-Kauapuhi Government Lands (Wall 1914) showing *'ili* along the eastern portion of the Project corridor

3.3.1 Habitation and Subsistence

Archaeological investigations and historic documents suggest that many of the *ahupuaʻa* within the *moku* of Koʻolaupoko contained well-developed fishpond systems and stream-fed irrigated upland terraces. The estuary system of Kāneʻohe Bay—the largest anywhere in the Hawaiian archipelago—contained lagoons and productive fisheries protected by broad fringing reefs. Hawaiians harvested *ʻamaʻama* (mullet), *awa* (milkfish), and other fish in the brackish waters of at least 30 *loko iʻa* on Kāneʻohe Bay during pre-Māhele times (Devaney et al. 1982:114, 143–144; Summers 1964:2), most of which have been destroyed (Devaney et al. 1982:139).

Frequent rainfall, ample streams, broad valley bottoms, and flatlands between the mountains and the sea provided excellent conditions for *loʻi kalo* and other forms of irrigated agriculture in Kāneʻohe and neighboring *ahupuaʻa*, such as crops of *ʻuala*, *uhi* (yam), *maiʻa* (banana), *hala* (pandanus), *wauke* (paper mulberry), *ōlonā* (a native shrub used for cordage), and *ʻawa* (kava) (Handy and Handy 1972:456). Through the construction of *ʻauwai*, Hawaiians diverted stream water for terraced taro cultivation in the *mauka* and *makai* regions of Kāneʻohe Ahupuaʻa (Handy and Handy 1972:45, 271–272). Recent archaeological surveys near the Kāneʻohe WWRTF documented a taro terrace (Clark and Riford 1986) and subsurface agricultural soil indicative of taro production (Hammatt and Borthwick 1989). One of the main preparations of taro was *poi* (pounded taro) (Figure 17). In nearby Heʻeia Ahupuaʻa, remnants of the vast inland *loʻi* system were only destroyed recently with the construction of the H-3 Freeway (Becket and Singer 1999:131).

The aquacultural and agricultural base of the region supported a dense population (Handy and Handy 1972:272). Archaeological surveys in the *mauka* regions of the *ahupuaʻa* of Kāneʻohe revealed several habitation and agricultural sites, including terraces used for taro cultivation (Kirch 1985:113). One inland settlement in particular, Luluku (Figure 18), once contained the most extensive early wetland agricultural complex on Oʻahu (Allen 1987:265). This archaeological site contains irrigated terraces radiocarbon dated to A.D. 500, and the stratigraphic sequence reflects a long period of continued use (Allen 1987:265). An archaeological site in close proximity to the Kāneʻohe WWRTF contains a vast assemblage of lithic artifacts radiocarbon dated to A.D. 1070–1405, which suggests that this area housed craftsmen specializing in the production of adzes and other stone tools (Clark and Riford 1986). Archaeological sites at Nuʻupia Fishpond adjacent to the Kailua WWTP similarly contain basalt tools, adze blanks, and flakes associated with stone tool manufacture (Hammatt et al. 1985; Jackson et al. 1993). Very few marine shellfish midden were recovered archaeologically, which suggests that Hawaiians once lived near the fishpond on a temporary or periodic basis (Jackson et al. 1993:78).

Figure 17. 1893 Photograph by J.J. Williams of *poi* pounding, taken near Kawa Stream in Kāne‘ohe Ahupua‘a (Scott 1968:727)

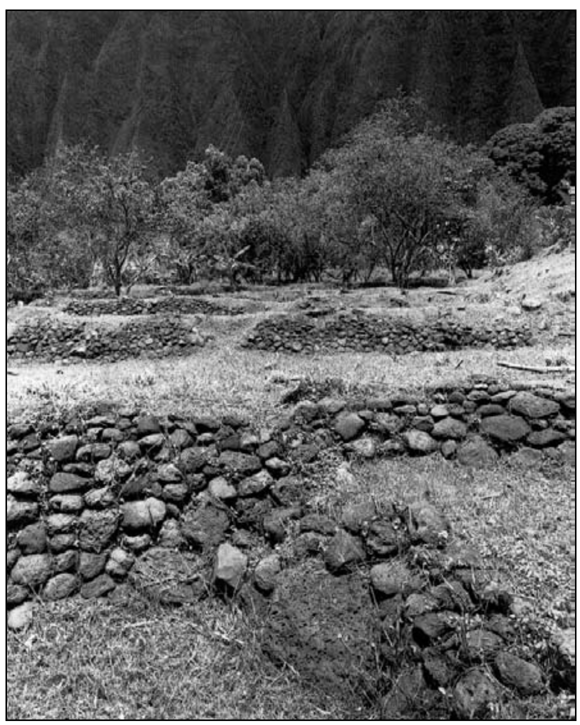

Figure 18. Inland settlement of Luluku, dating to A.D. 500 (Landgraf 1994:108)

3.3.2 Wahi Pana

A Hawaiian *wahi pana* "physically and poetically describes an area while revealing its historical or legendary significance" (Landgraf 1994:v). *Wahi pana* are sacred places that include such cultural properties as *heiau*, *loko iʻa*, *ala hele* (trails), *ilina* and *iwi kūpuna* (ancestral bone remains), land divisions, and natural geographic locations, such as streams, peaks, rock formations, ridges, and offshore islands and reefs that are associated with culturally significant beliefs or events. A *wahi pana* leaves an imprint on the landscape even if its tangible properties no longer exist, as the *mana* (divine power) of previous people and events associated with this space continues to manifest itself. For example, the stereotypical *heiau* is composed of terraces, enclosures, walls, mounds, or upright stones, but *heiau* can also be sacred places on a landscape that lack built structures, natural landscape features such as rock outcroppings, and earthworks where *mana* is concentrated and transferred between the deities and worshippers (Becket and Singer 1999:xix-xx).

The *wahi pana* of Kāneʻohe Ahupuaʻa link the *kamaʻāina* and *kūpuna* to their past. This section traces the *wahi pana* from the mountain peaks and valleys to the lowlands and coasts and further to offshore islands. For clarity and consistency, the locations of the cultural properties are bolded in the text and labeled on a map if their locations are known (see Figure 14). In addition, all *wahi pana* meanings are cited from Pukui et al. (1974) unless otherwise noted and spelling and use of diacriticals follow Pukui et al. (1974).

3.3.2.1 Place Names

Koʻolaupoko, the traditional name for the *moku* encompassing Kāneʻohe, translates literally as "the short windward" in contrast to the northern half of this coastline known as Koʻolauloa, "the long windward." This may reflect the relative short distance from the sea to the great *pali* of the Koʻolau Mountains, which seem to loom directly over much of this district. The meaning of Kāneʻohe may come from *kāne* (man) in reference to the god of creation and *ʻohe* (bamboo). As *kāne* also means "husband," the derivation of the name Kāneʻohe may also be rooted in a *moʻolelo* about a woman who compared her husband's cruelty to the cutting edge of a bamboo knife (Clark 2002). The name Kāneʻohe may also be derived from *ʻohe*, which is said to be one of the *kinolau* (body forms) of the god Kāne (Abbott 1992:15).

The mountainous sections of the *ahupuaʻa* of Kāneʻohe contain many *wahi pana* connected to the stunning landscape of the *pali*, with towering *puʻu* (peaks) over the sheer cliff rock faces overlooking the upland forests. The beauty of the *pali* is captured in the following *ʻōlelo noʻeau*: "*Na pali hāuliuli o ke Koʻolau*," which means "The hills and cliffs of the windward side of Oʻahu are always dark and beautiful with trees and shrubs" (Pukui 1983:249). This area at the base of the *pali* is particularly rich in *wahi pana*.

The northern mountainous section of Kāneʻohe Ahupuaʻa is dominated by **Puʻu Keahiakahoe** (the fire of Ka-hoe Hill), the tallest *puʻu* on the Koʻolau mountain range (Figure 19). The name of the peak stems from the tension between two brothers, Kahoe and Pahu (see 3.4.3.2 for the *moʻolelo* of Keahiakahoe). The tears of their sister, Loʻe, formed a spring in front of the *pali* of Keahiakahoe called **Loʻe wai** (Hawaiian Ethnological Notes ms:2181, cited in Sterling and Summers 1978:206).

Beneath Puʻu Keahiakahoe are three *pana* (distinguished places)—**Hiʻilaniwai** (cherished waters), **Kahuaiki** (the small fruit), and **Mamalahoa** (splintered paddle). These three streams are considered the wives of Kāne with whom he would meet secretly at the waters' junction (McAllister 1933:177). McAllister located the streams near Puʻu Keahiakahoe while Handy and Handy (1972) situated them near **Puʻu Lanihuli**. Hiʻilaniwai, which also means "carrying heavenly waters," emerges from a rocky precipice in the mountains of Kāneʻohe (Saturday Press 1883, cited in Sterling and Summers 1978:207). In a secluded dell near the base of the *pali* stood a stone altar of the same name as the stream Hiʻilaniwai, where a priest performed a ritual called Hui-Wai (Union of Water) for the dedication or offering of a child to a deity for a specific purpose (Parker ms:7, cited in Sterling and Summers 1978:207).

A battle between the gods of light and the gods of darkness for possession of springs with supernatural powers took place farther downstream of Hiʻilaniwai, and the scene was fenced off to become **Ka-Pa-Puaa** (the pigpen) (Parker ms:7-8, cited in Sterling and Summers 1978:209). Just beneath Keahiakahoe was a pigpen of Kāne called **Papuaʻa a Kāne** (McAllister 1933:177). A spring called **Kumukumu** was connected to the *heiau* Kukuiokāne at the base of the *pali* (McAllister 1933:177).

The southern mountainous section of Kāneʻohe Ahupuaʻa is highlighted by the dramatic landscape of the Nuʻuanu Pali, which contains numerous *wahi pana*. At the base of the cliffs, a man named Pakuanui would either ambush travelers descending the Pali Trail or kill an unsuspecting traveler with a *pōhaku puka* (trap door rock) suspended above the door to his house on a section of land known as **Kamaikola** (McAllister 1933:181). **Kekele** (damp), a place once abundant in *hala*, was fragrant with *hala* blossoms and bountiful in *hala* fruit for lei-making (Pualewa 1866, cited in Sterling and Summer 1978:221) (Figure 20). One *ʻōlelo noʻeau* captures the importance of this particular fragrance: "*Na hala o Kekele*," which translates as "The *hala* grove of Kekele" (Pukui 1983:242), while another *ʻōlelo noʻeau* attaches a different meaning to Kekele: "*Hopu hewa i ka ʻāhui o Kekele*," which translates as "[One] grasps the pandanus cluster of Kekele by mistake" and refers to a person who meets with disappointment (Pukui 1983:119).

A hill at the base of the *pali* called **Nā Maka o Kane** (the Eyes of Kāne) resembled a human face in shape; below the smooth brow of a hill, a tapering projection appeared as a nose, two slight depressions appeared as the hollow eye-pits on a human skull, and farther down other features highlighted the facial muscles (Parker ms:25–26, cited in Sterling and Summers 1978:220). **Hoʻoleinaʻiwa** (place where frigate birds leap) consists of over twenty large unusually weathered boulders resting on a hill in the *ʻili* of Hoʻoleinaʻiwa at the base of the mountains (Landgraf 1994:106) (Figure 21). There is no written documentation on this culturally significant site, but the tee-off area for the Koʻolau Golf Course was moved to preserve these *pōhaku* that appear similar to the birthing stones of Kūkaniloko (Landgraf 1994:106).

The path of the old Pali Trail started at **Ka-hoʻo-waha-pōhaku**, where people would ascend the cliff to reach a spring called **Ka-wai-kilo-kanaka** (the water for spying on people), named after the clearness of the reflection of the person in that water (Kaaia 1874, cited in Sterling and Summers 1978:224). Another name for the spring is **Wai-aka** (shadowy water), or **Waikolokohe**, which stems from the reflection in the water of wind-blown *lehua ʻāhihi* (a bush) blossoms (Pooloa 1919, cited in Sterling and Summers 1978:224). From there one would climb to a rock called **Ka-ipu-o-Lono**, where a misplaced step would lead to one's fall and likely death

(Kaaia 1874, cited in Sterling and Summers 1978:224). From there to the *nuku* (mountain pass) of Nu’uanu was a land section called **Ka-pili**, and past the *nuku* was a division of land called **Ka-holo-a-ke-ahole** (Kaaia 1874, cited in Sterling and Summers 1978:224). Along the way toward the summit was a pool named **Ka-wai-kilo-kohe** (the water for spying on vagina) (Na Anoai o Oahu nei 1930, cited in Sterling and Summers 1978:224). **Ka Nuku** (the mountain pass) at the Pali lookout (Landgraf 1994:98) (Figure 22) was also called Ka-pili, as *pili* (to join) refers to the adjoining cliffs (Kaaia 1874, cited in Sterling and Summers 1978:224). Two famous stones, **Hapuu** and **Kalanaihauola**, sat at the top of the Nu’uanu Pali (Makaikeoe 1908, cited in Sterling and Summers 1978:224), to which travelers left offerings of flowers and fruit to ensure a safe journey over the *pali*. On the top of the northern peak of the Nu’uanu Pali is a **cave** to which the spirit of Pumaia flew (Fornander 1916–17:474). **Lanihuli** is the *pu‘u* above the Nu‘uanu Pali. The *‘ōlelo no‘eau*, “*Kāwelu holu o Lanihuli*,” or “the swaying grass of Lanihulu,” refers to the rippling in the strong breezes blowing over the *pali* (Pukui 1983:180) (Figure 23).

The southern coastal region of Kāne‘ohe Bay in the vicinity of the Project area contains several place names. The subsurface Project corridor runs under the *‘ili* of **Waikalua** (water of the *lua* [type of dangerous hand-to-hand fighting] fighter or water of the pit), **Keana** (the cave), **Mahinui** (great champion), **Kalāheo** (proud day), **Pa‘alae**, **Pū‘ahu‘ula** (the feather-cloak spring), **Māla‘e** (clear), and **‘Aikahi** (eat scrap [as the sides of a *poi* bowl; thus to eat all]). A **ditch** once separated Punalu‘u and Waikalua to contain the pigs of royalty (McAllister 1933:178). **Oneawa** (milkfish sand) was a place in Kailua Ahupua‘a that was famous for *‘ō‘io* (ladyfish, bonefish) and *awa* (milkfish), and the ridge between Kailua and Kāneohe was named **Oneawa Hills** in 1971 (Pukui et al. 1974). The *ōlelo no‘eau*, “*Ku ulu koa i kai o Oneawa*” translates as “The *koa* grove down at Oneawa,” and refers to canoes at Oneawa since they were made of *koa* (Pukui 1983:175). In addition, a small round hill with a long, narrow depression near Kāwa‘ewa‘e Heiau was the site of a ***hōlua*** (sled) course, which was destroyed for pineapple cultivation (McAllister 1933:181). Hawaiians from Kailua and Kāne‘ohe once died in great numbers at a spring called **Kinikailua-Manokaneohe** (*kini* literally means 40,000 and *mano* literally means 4,000) in the *‘ili* of Keana (McAllister 1933:179). The *‘ōlelo no‘eau*, “*Kini Kailua, mano Kāne‘ohe*,” which translates as “forty thousand in Kailua, four thousand in Kāne‘ohe,” refers to either the number of people that would die by sorcery from a woman named Kawaiho‘olana keen to avenge the murder of her son, or sorcery to destroy Kamehameha’s enemies on O‘ahu (Pukui 1983:193). A hill, also named named **Pu‘u Pahu**, marks the grave of Manu-ka (Frightener-of-birds) (Rice 1923).

The windward section of the peninsula of Mōkapu (sacred island) belonged to the *ahupua‘a* of He‘eia and the leeward section was part of the *ahupua‘a* of Kāne‘ohe (Figure 24). A spring named **Hawai‘iloa** (long, or distant, Hawai‘i) once brought fresh water to the top of **Pu‘u Hawaiiloa (**long, or distant, Hawai‘i hill) (McAllister 1933:185). This crater is part of the *‘ili* of **Heleloa** (far travels) and a structure of terraces and walls appears to mark the *ahupua‘a* boundary of Kāne‘ohe and He‘eia (Tuggle and Hommon 1986:57–58) (

Figure 25).

The tallest peak on Mōkapu Peninsula is **Pu’u o Kaha‘i** (hill of Kaha‘i), named after the final resting place of a hero named Kaha‘i from Maui (Oahu Place Names ms; cited in Sterling and Summers 1978:215). Pele’s first landing place on O‘ahu was nearby at the crater **Ulupau**, which literally means "increasing soot" due to a volcanic eruption and the fumes that followed (Fiddler 1956) (Figure 26). **Pukaulua** (*ulua* [crevallem, jack and pompano fish] fish opening) is a ridge forming on one side of Ulupaʻu crater with a cliff face known as Kahekili's Leap that was named after an *aliʻi* who was an expert at *lele kawa* (diving into the sea from high cliffs) (Landgraf 1994:80) (Figure 27). **Waikulu** (dripping water) was the old name for Ulupaʻu and may refer to the water that rains down as the surf breaks against the coast (Landgraf 1994:84).

Mokumanu (bird island) is located off the peninsula of Mōkapu near Ulupaʻu and is part of the *ahupuaʻa* of Kāneʻohe (Figure 28). Kūhaimoana, a shark god, once lived on the leeward side of Mokumanu (Landgraf 1994:82).

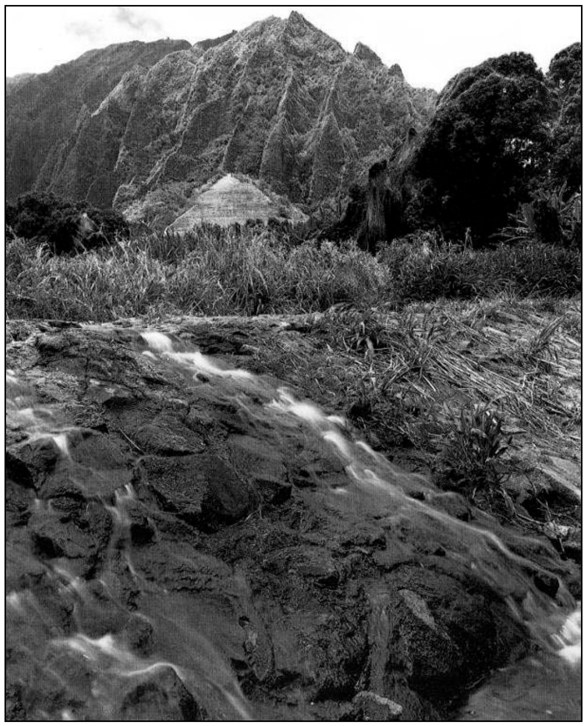

Figure 19. Keahiakahoe (Landgraf 1994:95)

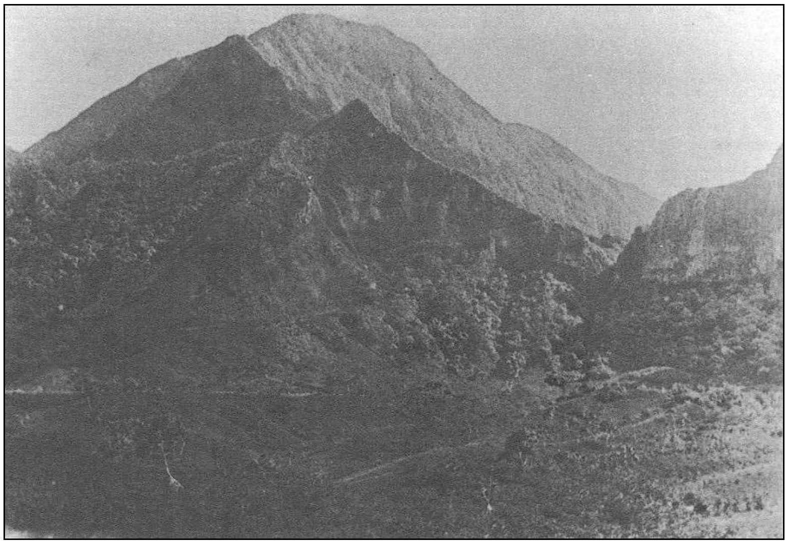

Figure 20. Kekele in the late 1880s with only a few *hala* trees left (Hawaiʻi State Archives, in Devaney et al. 1982:234)

Figure 21. Hoʻoleinaʻiwa (Landgraf 1994:107)

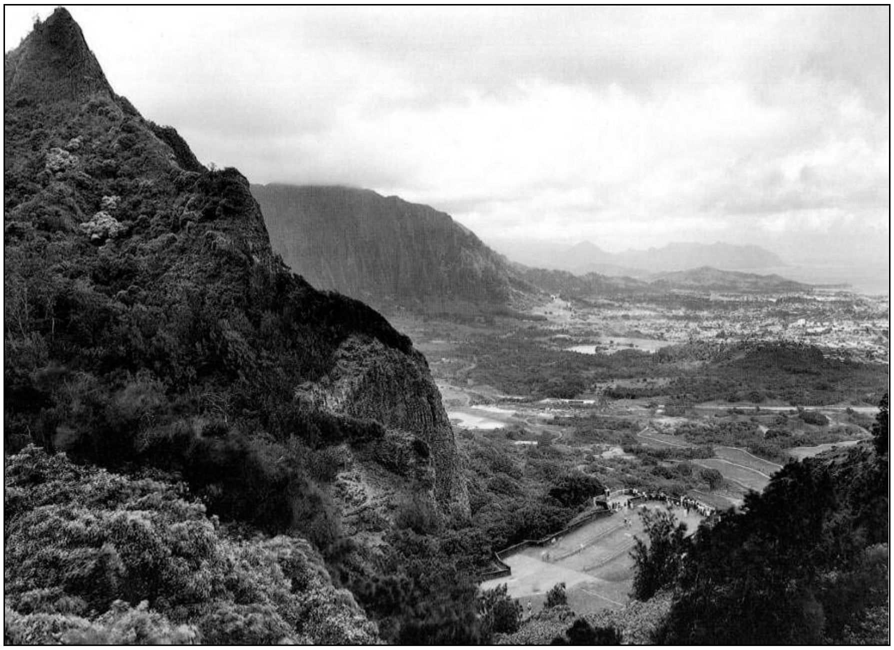

Figure 22. Ka Nuku (Landgraf 1994:99)

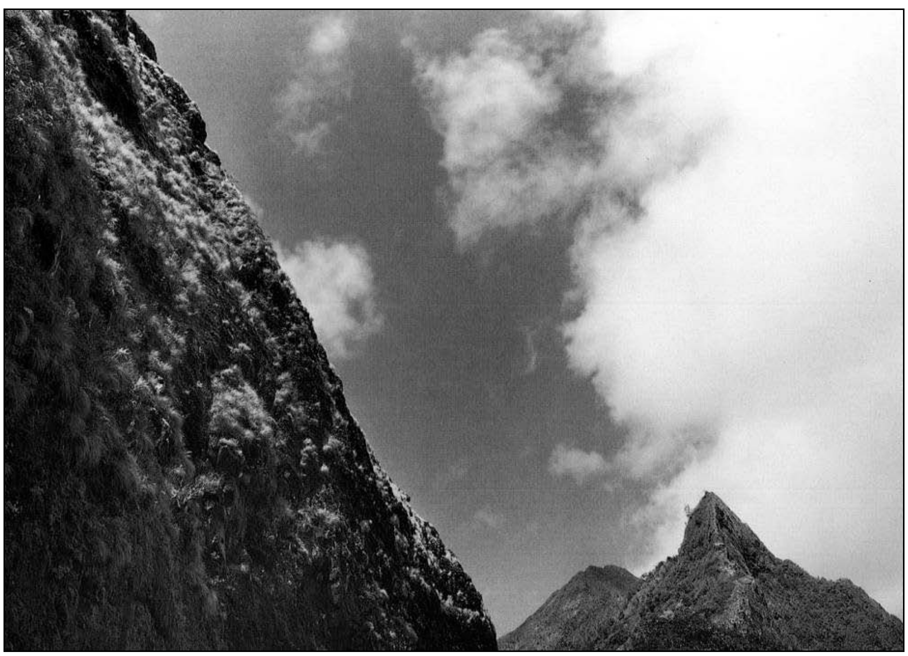

Figure 23. Lanihuli (Landgraf 1994:97)

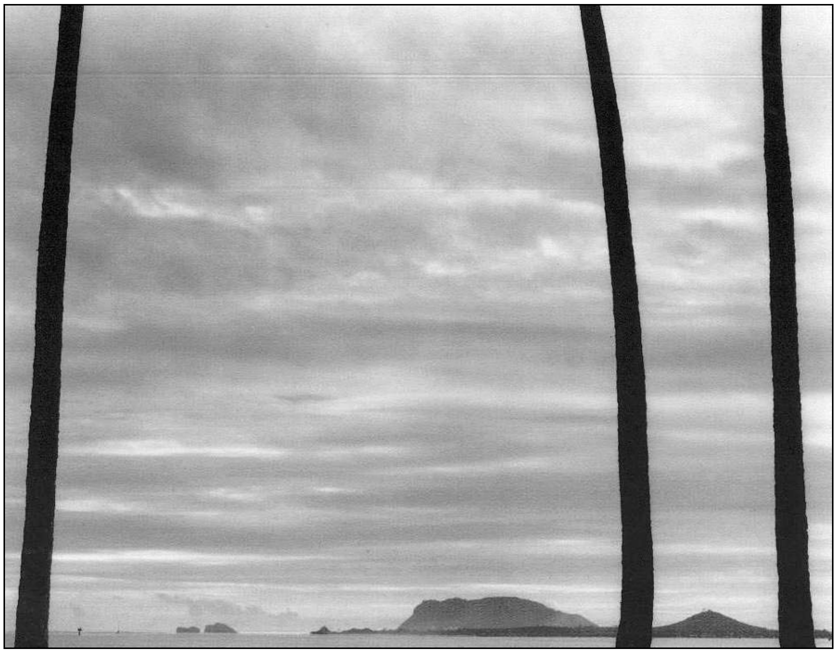

Figure 24. Mōkapu (Landgraf 1994:71)

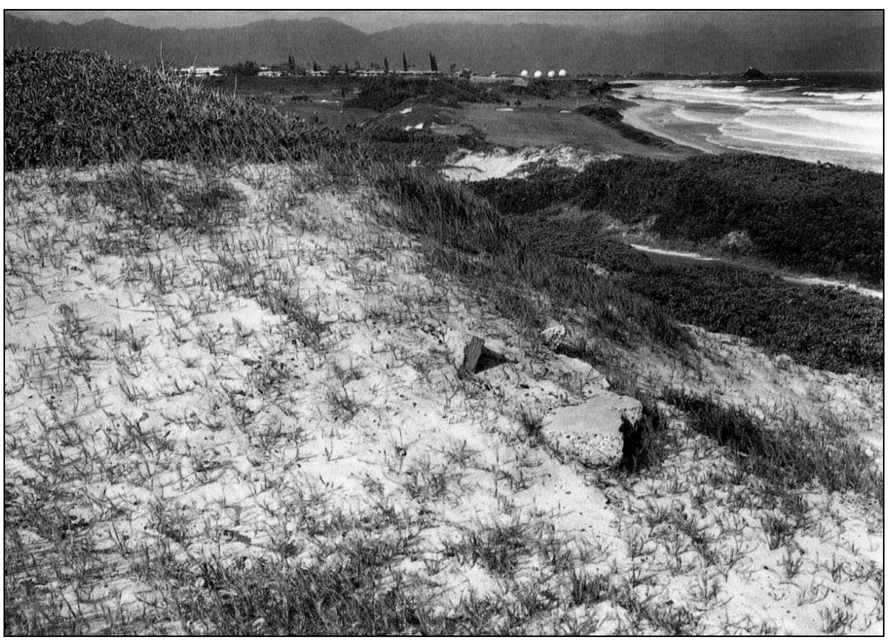

Figure 25. Heleloa (Landgraf 1994:77)

Figure 26. Ulupaʻu (Landgraf 1994:79)

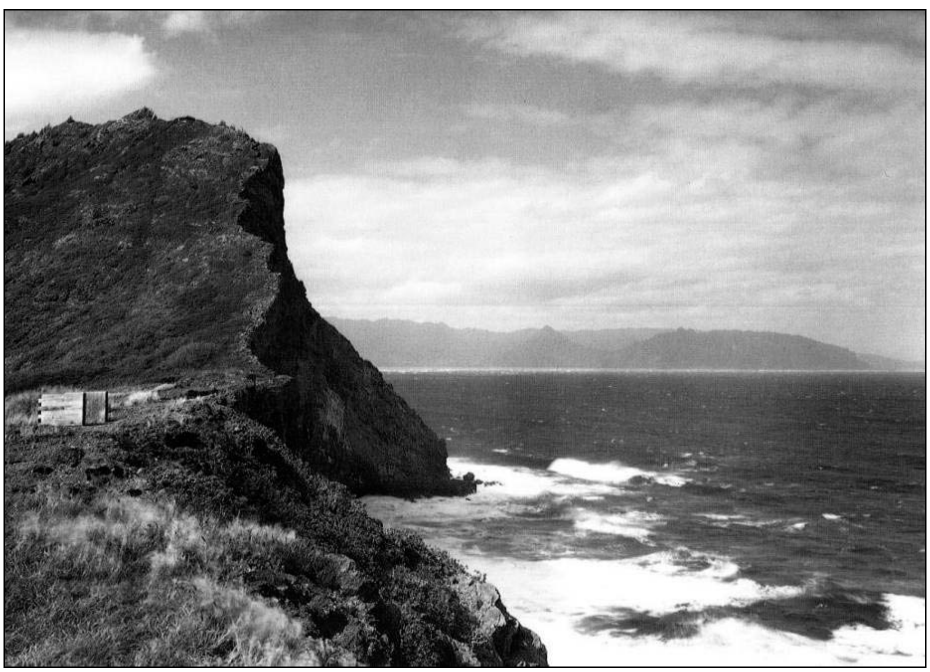

Figure 27. Pukaulua (Landgraf 1994:81)

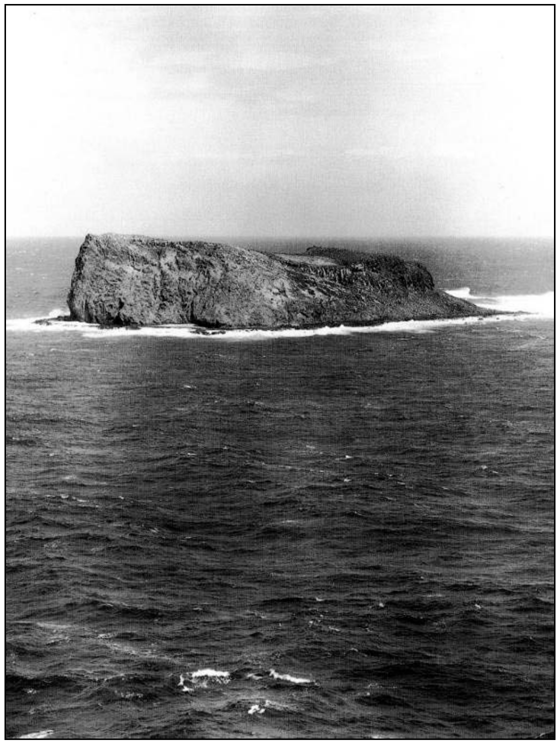

Figure 28. Mokumanu (Landgraf 1994:83)

3.3.2.2 Heiau

Archaeologists documented several *heiau* in Kāne‘ohe Ahupua‘a in the early twentieth century. Several of these are located in the mountainous regions of Kāne‘ohe at the base of the *pali*. Thrum (1916) noted that **Maunahuia Heiau** was in ruins near the foot of Lanihuli, but McAllister (1933:182) added that an unnamed *heiau*—most likely Maunahuia Heiau—contained three large paved terraces with a stone-lined depression facing the *pali*, most likely an *imu* (earth oven)). **Kukuiokāne Heiau** was supposedly destroyed during the pineapple plantation era (McAllister 1933:177) but was rediscovered with the construction of the H3 freeway (Neller 1989). Kukuiokāne (the light of Kāne) was the largest agricultural *heiau* in Kāne‘ohe, spanning a distance of one hundred and ninety meters and containing several terraces (Landgraf 1994:110) (Figure 29). This *heiau* is located fifty yards above the Luluku dryland agricultural terrace system (Landgraf 1994:110). **Pu‘uwāni‘ani‘a Heiau**, located on the ridge Pu‘uwāni‘ani‘a (hill of maligning talk) (Landgraf 1994:102), is now covered mostly with *waiwī* (strawberry guava) trees just below the Pali Highway and consists of two large eroded stones surrounded by a low wall (Landgraf 1994:102) (Figure 30). **Kaluaolomana** is another *heiau* on the ridge of Pu‘uwāni‘ani‘a (Landgraf 1994:104) (Figure 31), although Thrum (1916) listed Kaluaolomana as another name for Puuwaniania Heiau. In addition, Thrum (1916:90) listed **Pule** and **Kuakala** as two additional *heiau* near the *pali*.

Between the mountains and Kāne‘ohe Bay along the ridge dividing the *ahupua‘a* of Kāne‘ohe and Kailua near the Kāne‘ohe WWPTF is **Kāwa‘ewa‘e Heiau** (Figure 32). Kāwa‘ewa‘e is one of five *heiau* erected by the *aliʻi* ʻOlopana in the twelfth century (McAllister 1933:179). ʻOlopana plotted to sacrifice the pig demigod Kamapuaʻa at Kāwaʻewaʻe, which means "coral or stone used to rub off pig bristles," (Landgraf 1994:112) but instead Kamapuaʻa killed ʻOlopana (Thrum 1916:90) (see Section 3.4.3.4 for the *moʻolelo* of Kamapuaʻa and Kāwaʻewaʻe Heiau). The massive walls of the *heiau* measure five feet wide and from four to seven feet high, and a terrace was positioned on the north side of the walled enclosure (McAllister 1933:179). Another *heiau* built by ʻOlopana located on a ridge facing the *pali* was **Puumakani Heiau** (windy hill); however, the stones were removed for the building of a cattle corral (McAllister 1933:181)

Other *heiau* are located *makai* of the Kāneʻohe WWPTF. Chief Laʻamaikahiki arrived from Tahiti in the 1200s and built several *heiau* farther *makai* along the coast of Kāneʻohe Bay (Thrum 1916:90). He threw out sand as a resting place for the canoes, and this is where the *heiau* **Nāonealaa** (the sands of Laʻa) was built (Kamakau 1867; Thrum 1916:90), (see Section 3.4.3.3 for the *moʻolelo* on Nāonealaa). Other *heiau* that once existed near the coast of Kāneʻohe Bay included **Puʻupahu Heiau** (McAllister 1933:177) and **Kalaoa Heiau** (McAllister 1933:178). **Ahukini Heiau** (altar for many blessings) was constructed about 1200 feet from the sea with low walls built of very small stones (McAllister 1933:179).

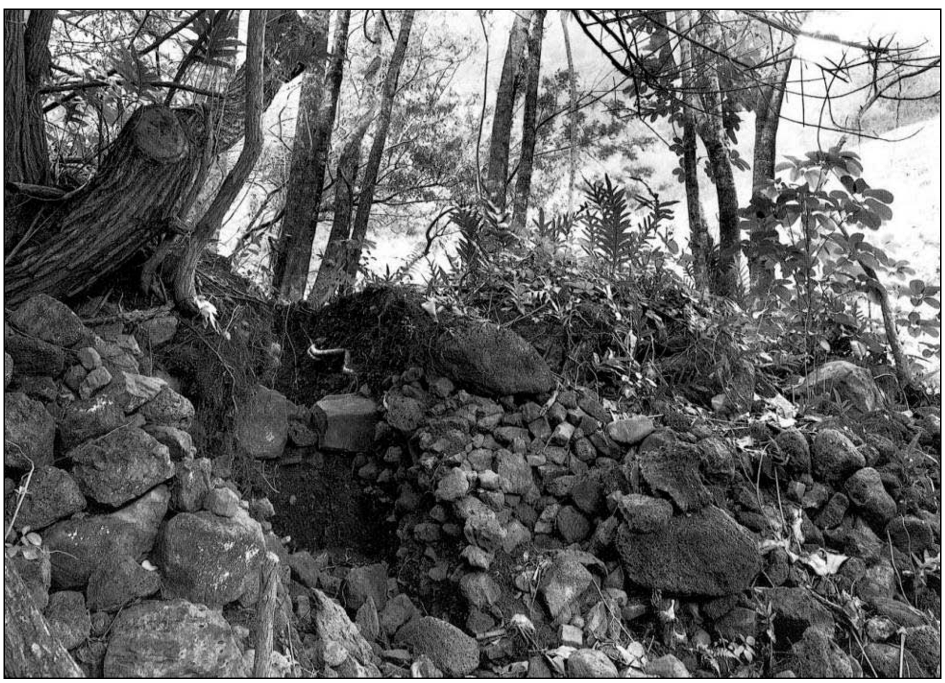

Figure 29. Kukuiokāne Heiau (Landgraf 1994:111)

Figure 30. Pu‘uwāni‘ani‘a Heiau, covered with *waiwī* trees (Landgraf 1994:103)

Figure 31. Kaluaolomana Heiau (Landgraf 1994:105)

Figure 32. Kāwaʻewaʻe Heiau (Landgraf 1994:113)

3.3.2.3 Loko iʻa

The northern coastal strip of Kāneʻohe Ahupuaʻa contained three fishponds. The fishpond **Kalokohanahou** (the repaired pond), which incorporated a small island into its wall, was just below Puʻu Pahu (McAllister 1933:177). The fishpond **Kanohuluiwi**, which means *ʻiʻiwi* (scarlet Hawaiian honey creeper) feathers (Landgraf 1994:114), covered an area of about two acres with its narrow rock walls (McAllister 1933:178) (Figure 33). Adjacent to Kanohuluʻiwi was the seven-acre fishpond **Waikapoki**, which was destroyed in the 1950s to build a marina (Devaney et al. 1982:146–152). Another fishpond, **Punaluu** (spring dived for), covered an area of about twelve acres with its basalt walls reaching 1600 feet (McAllister 1933:178).

Hawaiians constructed three fishponds farther south along the coast near the Kāneʻohe WWPTF, two of which still exist. **Waikalua Loko** is located along the southern shore of Kāneʻohe Bay immediately *makai* of the Kāneʻohe WWPTF (McAllister 1933:178) (Figure 34). The *kuapā* (fishpond wall) extends approximately 1,400 linear feet to enclose 11 acres of water and has three *mākāhā* (sluice gates), which are the primary sources of seawater to the pond from tidal movements in Kāneʻohe Bay. While Waikalua literally means "water of the *lua* fighter" or "water of the pit," Wai-ka-lua translate literally as "the two freshwaters" and may refer to the two streams that originally provided fresh water to the fishpond—Kāneʻohe Stream and Kawa Stream. Kāneʻohe Stream was one of the largest watersheds in windward Oʻahu and Kawa Stream provided fresh water to the Waikalua Loko Fishpond until it was channeled due to residential development. Waikalua Loko still exists today and is cared for by the Waikalua Loko Fishpond Preservation Society. The adjacent fishponds **Waikalua** and **Loko Keana** once shared a common *kuapā*. Remnants of Waikalua Fishpond still exist; however, it is covered with mangrove. Loko Keana has been filled.

Directly east of Waikalua Loko, Waikalua, and Keana Fishponds was another trio of fishponds called, from west to east, **Mikiola** (active and alive), **Kapuʻu,** and **Mahinui** (great champion) (McAllister 1933:179). Farther east along Kāneʻohe Bay are three small fishponds called **Keaalau**, **Hanalua,** and **Papaa** (secure enclosure), each named after the land to which they are adjacent (McAllister 1933:182).

Three adjoining fishponds once separated Mōkapu from the main land of Kāneʻohe. **Halekou** (*kou*-wood house) covered 92 acres with a 1600 foot long wall (McAllister 1933:184) (Figure 35). It shared a common wall with the **Nuʻupia** (arrowroot heap), located immediately north of the Kailua WWTP, which enclosed 215 acres with a 1500 foot long wall (McAllister 1933:184) (Figure 36). Nuʻupia was the father and Halekou the mother of a boy named Puniakaiʻa, who tamed Uhumākaʻikaʻi, the parent of all fishes, to gain control of all the fishes in the sea (Landgraf 1994:88). The pond **Kaluapuhi**, which means "eel pit" because an eel-shaped rock was in a cave (Pukui et al. 1974:79), was the original pond that encompassed both Nuʻupia and Halekou (McAllister 1933:184; Tuggle and Hommon 1986:64) (see Section 3.4.3.5 for a brief *moʻolelo* on Nuʻupia, Halekou, and Kaluapuhi). Kaluapuhi was connected with Kailua Bay by one *mākākā* (McAllister 1933:184). Rectangular salt pans called **Kapoho** (the depression) or **Paʻakai** (salt; Landgraf 1994:90) were constructed adjacent to Kaluapuhi Pond on the low banks of the land to collect evaporated salt from seawater (MacCaughey 1917, cited in Sterling and Summers 1978:214) (Figure 37).

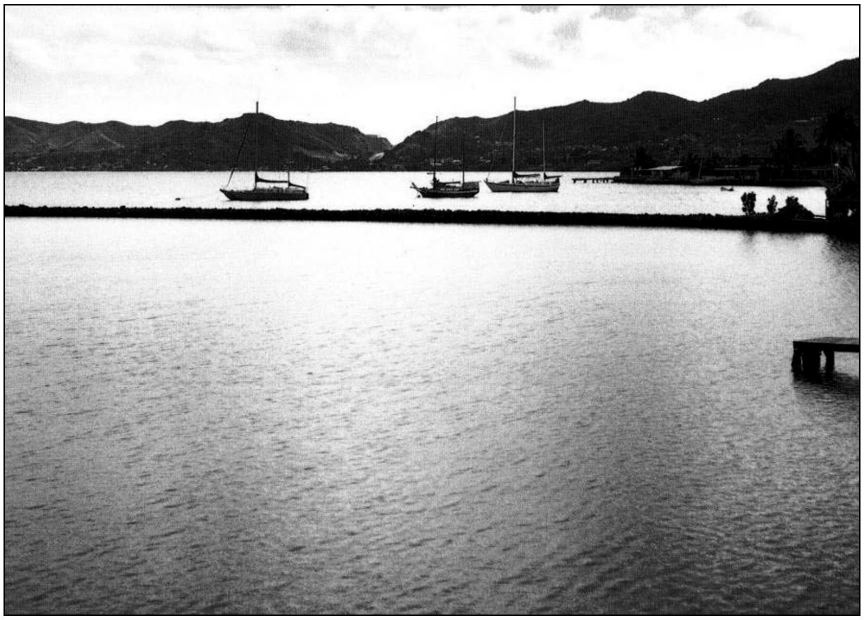

Figure 33. Kanohuluʻiwi (Landgraf 1994:115)

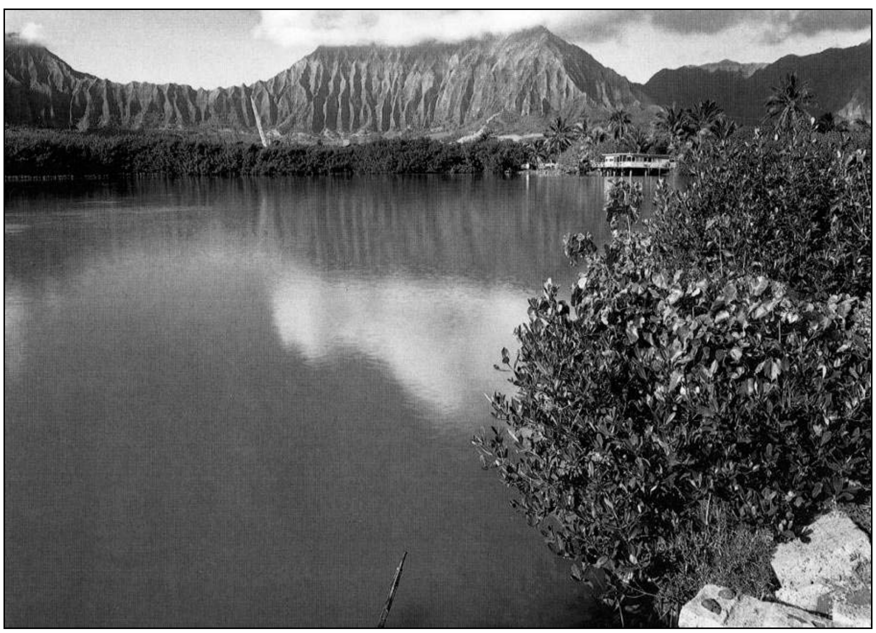

Figure 34. Waikalua Loko (Landgraf 1994:117)

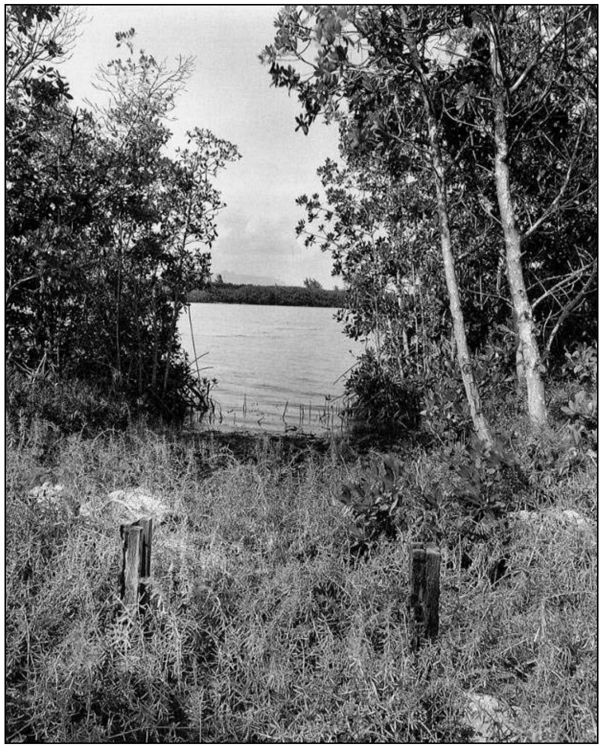

Figure 35. Halekou (Landgraf 1994:87)

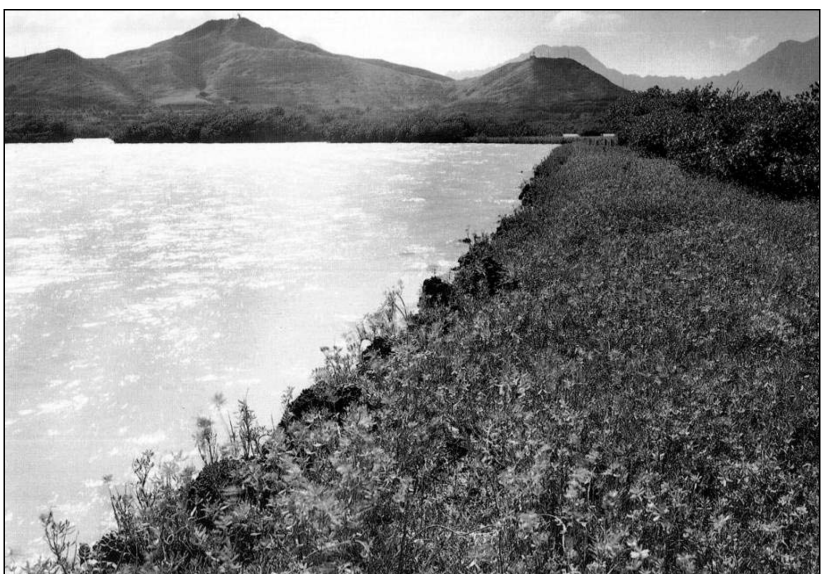

Figure 36. Nuʻupia (Landgraf 1994:89)

Figure 37. Kaluapuhi and Paʻakai (Landgraf 1994:91)

3.3.2.4 Ala Hele

Ala hele (pathway or trail) once served to connect the various settlements throughout Oʻahu, including a coastal route that circled Oʻahu and trails that traversed the mountain ranges. John Papa ʻĪʻī (1959) documented early post-Contact trails on the leeward side of Oʻahu, but there is little information on the network of *ala hele* that once undoubtedly connected Kāneʻohe to outlying communities. For example, a trail once ran along the base of the *pali* in Kāneʻohe. Richard H. Davis of the Hawaiian Trail and Mountain Club recently rediscovered the trail, and it was named the **Likeke Trail** in honor of his Hawaiian name (Ball 2000:199).

The most impressive *ala hele* in the *ahupuaʻa* of Kāneʻohe was the **Pali Trail**, which traversed the sheer cliff rocks of the Nuʻuanu Pali (Figure 38). According to the diary entry of Reverend R. Tinker in 1831, Hawaiians used the trail to transport taro, potatoes, *poi*, fowl, goats, and pigs between windward Oʻahu and Honolulu (Thrum 1901:89). Lord Byron, Commander of the *H.M.S. Blonde*, captured the descent of the Pali Trail in an entry in the ship's log in 1825, in which he inscribed that "The descent to this plain…is the most fearful imaginable…where a false step would be inevitable destruction" (Byron 1826, cited in Sterling and Summers 1978:225). Parts of this steep path later became incorporated into the stone-paved horse trail in 1845, the newly constructed Pali Road in 1897, and recent improvements starting in 1952 that led to the existing Pali Highway (Devaney et al. 1982) (see Section 3.4.5).

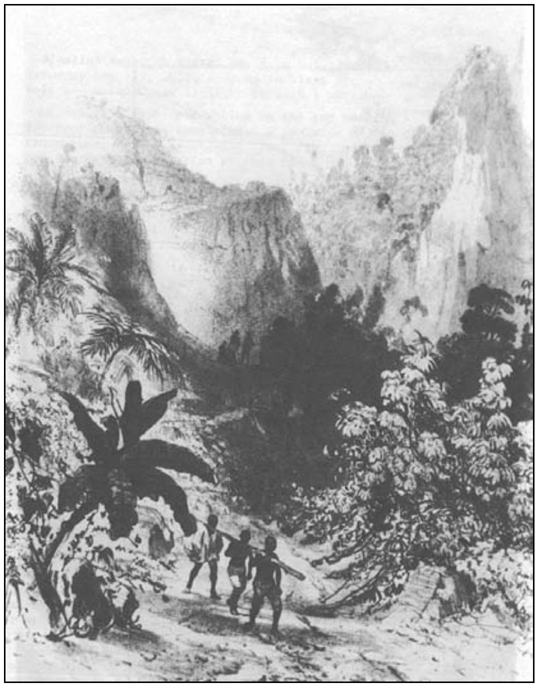

Figure 38. The old Pali Trail, 1836; lithograph of painting by Capt. V. B. Fisquet (R. J. Baker Collection and BPBM Collection, in Devaney 1982:174)

3.3.2.5 Ilina

Hawaiians cared for the dead with a variety of *ilina*, including cremation burials, burial caves, burials in the sand and earth, burials directly underneath house floors, burials in the platforms of *heiau*, and burials marked on the surface by stone terraces, mounds, platforms, and other monuments (Kirch 1985:238–242). On the leeward half of Mōkapu Peninsula in Kāneʻohe Ahupuaʻa, over 500 sand burials have been unearthed. The Mōkapu dunes were most likely established burial grounds for the residents of several villages located on the windward half of the peninsula in Heʻeia Ahupuaʻa (Sterling and Summers 1978:217). This burial ground included commoners and people of higher status, as several of the *ilina* include ornaments, such as the *lei niho palaoa* (Kirch 1985:111). A limestone cobble pavement close to the northern boundary of the Kailua WWTP may cover a burial (Jackson et al 1993). There is no documented evidence from archaeological surveys, historical records or oral traditions of *ilina* or *iwi kūpuna* within the Project area.

3.3.3 Moʻolelo of Wahi Pana

There are several *moʻolelo* associated with place names and other *wahi pana* of Kāneʻohe Ahupuaʻa near the Project area. The following section summarizes these *moʻolelo* (see Appendix D for expanded versions of some of these *moʻolelo*).

3.3.3.1 Kāne‘ohe

One *mo‘olelo* traces the origin of the name Kāne‘ohe to a man’s musical renditions of *‘ohe*. Paki (1972:29–30) chronicles the adventuress of two childhood playmates, Hano-ihu and Pu‘ili. One day, Hano-ihu wandered to the upland forests and did not return. Pu‘ili set out to find him, and upon hearing the lyrical sound of bamboo trees in the wind, she beat two bamboo sticks together. Then, saw her playmate and Kāne‘ohe, the Bamboo Man. She learned that he had invented the bamboo nose flute as a child, which he now named after the boy (Hano-ihu). Kāne‘ohe also named the notched bamboo sticks after the girl (Pu‘ili) (see Appendix D for the expanded *mo‘olelo*).

3.3.3.2 Keahiakahoe

The *mo‘olelo* of Keahiakahoe illuminates the entire landscape of Kāne‘ohe Ahupua‘a and provides a perspective on various forms of subsistence. Kahoe, a farmer in the mountains at Kea‘ahala, and his younger brother Kahuauli, a farmer in the uplands of Pu‘u Kahuauli overlooking the Luluku area, always gave *poi* (pounded, cooked taro) to their coastal-dwelling brother, Pahu. In return, Pahu, a fisherman living near the coast on Pu‘u Pahu (Pahu Hill), merely gave Kahoe his leftover bait fish. When Lo‘e, their sister who lived on Moku o Lo‘e, told Kahoe that his brother was a good fishermen, Kahoe realized Pahu’s deceit. A few months later a shortage of fish forced the farmers in the mountains to cook at night for fear of drawing hungry fishermen from the shore during the daytime. However, the smoke from Kahoe’s fire drifted far up a cliff before it could be seen, so he did not have to cook at night (Hawaiian Ethnological Notes ms, Vol.2., cited in Sterling and Summers 1978:206). One day Lo‘e saw Pahu looking up toward the summit of the *pali* and stated “So, now all you can do is stand and look at Kahoe’s fire [*Ke ahi a Kahoe*]” (Landgraf 1994:94) (see Appendix D for the expanded *mo‘olelo*).

3.3.3.3 Nāoneala‘a

The *mo‘olelo* of La‘amaikahiki describes the arrival of a La‘a, a navigator from Kahiki on the north side of the mouth of Kāne‘ohe Stream near the Project area (Kamakau 1867, cited in Sterling and Summers 1978:209–210). La‘a was accompanied on his voyage by forty paddlers and the following specialists: Kaikaikūpolō, his *kahuna* (priest); Luhaukapawa, his *kuhikuhi pu‘uone* (diviner); Kūkeaomihamiha, his *kilo* (astronomer); Kupa, his *ho‘oheihei pahu* (drummer); and Mā‘ulamaihea, his *kāula* (prophet). He threw out sand as a resting place that became known as Nāoneala‘a (sands of La‘a). La‘a brought *hula* and temple drums that had been previously unknown to the islands. After settling at Nāoneala‘a, he founded a chiefly class of rulers (Landgraf 1994:116). Nāoneala‘a Heiau once stood near the sandy beach (Thrum 1916:90).

3.3.3.4 Kāwa‘ewa‘e Heiau

Windward O‘ahu is famous for *mo‘olelo* of Kamapua‘a—the half man, half pig demigod renowned for making mischief and for his masterful escapes from retribution for his chicken and taro thievery. One *mo‘olelo* centers on Kamapua‘a and the Kāwa‘ewa‘e Heiau. Thrum (1907:48) reports that the high chief ‘Olopana erected Kāwa‘ewa‘e Heiau in the beginning of the twelfth century, while Fornander (1878:23) describes how *menehune* (legendary race of small people who built structures by night) constructed the *heiau*. ʻOlopana, depending on which story is being told, was either the father or uncle of the notorious Kamapuaʻa. In a version of the story presented by Kalākaua (1990:142–147), Kamapuaʻa, embittered by ʻOlopana's rejection of this hog-child, retreats to the mountains where he attracts a band of like-minded thieves and commences to harass ʻOlopana, stealing his pigs, fowls and fruits as well as taking pleasure in breaking his nets, cutting adrift his canoes, and robbing his fishponds. Enraged by Kamapuaʻa's pillage and acts of rebellion, ʻOlopana orders his capture. After several battles and failed attempts to catch Kamapuaʻa, ʻOlopana's army succeeds in delivering Kamapuaʻa to the high chief. ʻOlopana oversaw the ceremonies leading up to the sacrifice of Kamapuaʻa, but the high priest had coerced the executioner and his assistants to make it appear as if they had killed Kamapuaʻa. When ʻOlopana approached the sacrificial altar, Kamapuaʻa grabbed a dagger left by the high priest and used it to strike down ʻOlopana. The high priest released Kamapuaʻa from custody, but the residents banded together to hunt him down. Kamapuaʻa and his cohorts eventually sailed away from Oʻahu for the windward islands in search of refuge (see Appendix D for the expanded *moʻolelo*).

3.3.3.5 Nuʻupia Fishpond

According to Landgraf (1994:88), Nuʻupia was the father and Halekou the mother of a boy named Puniakaiʻa, who tamed Uhumākaʻikaʻi, the parent of all fishes, to gain control of all the fishes in the sea. Fiddler (1956:13) notes that the watery expanse of Kaluapuhi, which originally encompassed Nuʻupia and Halekou, was guarded by an eel. Seeking a shorter passage from Kāneʻohe Bay to Kailua Bay, the eel shaped Kaluapuhi by tunneling through Mōkapu.

3.3.4 The Reigns of Kahekili and Kamehameha

The earliest historic accounts relate major battles of conquest during the late 1700s. The feeding of such amassed armies necessitated procuring valuable food supplies and highly productive locales. In the 1780s, Kahekili, the *mōʻī* (king) of Maui, fought for control of Oʻahu from Kahahana, the *mōʻī* of Oʻahu, who sometimes resided in Kāneʻohe and Heʻeia. Kahekili met and defeated Kahahana in the valley of Nuʻuanu (Devaney et al. 1976:5). After his victory, Kahekili lived at Kailua while most of his *aliʻi* and followers stayed in Kāneʻohe and Heʻeia (Kamakau 1992:138).

Kamehameha followed much the same route as Kahekili some ten years later. When Kamehameha's fleet landed on the beaches of Waikīkī in 1795 to start his invasion of Oʻahu, Kalanikūpule and his chiefs were positioned strategically in the valley of Nuʻuanu. They could have fought at Kalanikūpule's home in Waikīkī but Kalanikūpule took his men to Nuʻuanu Valley (Kamakau 1992:172–173). Kalanikūpule had positioned cannon fortifications above the Nuʻuanu Pali on the ridge of the towering Kōnāhuanui peak at upper boundary of the *ahupuaʻa* of Kāneʻohe (James 2004). Two of these cannon fortifications remain as visible evidence of the historic clash that ensued (James 2004). The battle is called Kalelekaʻanae, which means "leaping *ʻanae*" (mullet) and refers to the way many Oʻahu armies of Kalanikūpule and some of their families chose to or were forced to jump to their deaths from the *nuku* (mountain pass) of the steep Nuʻuanu Pali rather than accept defeat from the warriors of Kamehameha (James

2004). At least 300 warriors from both sides died (Kamakau 1992:172–173). The following account vividly describes the final battle on the precipice overlooking the *ahupuaʻa* of Kāneʻohe:

> The forces of Kamehameha charged; in the onslaught many of the Oahuans were slain, and the rest pursued with great slaughter until they were driven to the end of the valley, which terminates in a precipice of six hundred feet, nearly perpendicular height, forming a bold and narrow gorge between the two foreclad-mountains. A few made their escape; some were driven headlong over its brink, and tumbled, mangled and lifeless corpses, on the rocks and trees beneath; others fought with desperation and met a warrior's death, among whom was Kalanikupule, who gallantly contested his inheritance to the last. (Jarves 1847:92)

Some of the weaponry from the Battle of Nuʻuanu has been discovered. A Japanese farming family living at the base of the Nuʻuanu Pali at the beginning of the twentieth century found several sling shot stones just below the *nuku* that were most likely used during the battle (Fanning 2008:96).

Fornander's (1878) narrative of this moment offers an alternate fate for Kalanikūpule, as he apparently escaped to the mountains with some of his men for several months, but was discovered and sacrificed to the Kamehameha's war god Kuhailimoko. After the battle of Nuʻuanu, Kamehameha became the sole ruler of Oʻahu, Molokaʻi, Lānaʻi, Hawaiʻi, and Maui (Kamakau 1992:172-173). He retained the *ahupuaʻa* of Kāneʻohe as his own personal property when he divided the conquered lands of Oʻahu to his warrior chiefs and counselors (ʻĪʻī 1959:69-70). His sons Liholiho and Kauikeaouli—Kamehameha II and Kamehameha III, respectively—inherited most of Kāneʻohe Ahupuaʻa (Kamakau 1992).

3.3.5 Pali Trail and Pali Road

The *ala hele* that once traversed the sheer cliff rocks of the Nuʻuanu Pali (see Section 3.7) has undergone several dramatic changes since the mid-nineteenth century. According to a letter written by Reverend R. Tinker in 1840, an American merchant named Hinckley first proposed making the old Pali Trail more passable, but a blacksmith named Beers first supervised cutting steps into the steepest sections and building an iron railing (Thrum 1901:89). In response to agricultural development in Kāneʻohe and other *ahupuaʻa* in windward Oʻahu, King Kamehameha III secured funds in 1845 to make the old Pali Trail accessible to horses. Sections of the path were paved with stones that enabled King Kamehameha III, John Young, and Dr. Gerritt P. Judd to traverse it on June 28, 1845. In 1861, Dr. Judd and Reverend E. Corwin made the first descent in a horse-drawn carriage (*Island Call* 1953). The Pali Trail was then widened to six feet, paved with stones, and the grade was lessened in most areas to 15% (Bishop 1898, cited in Devaney et al. 1982:165 (Figure 39).

In 1882, construction began to further widen the road to twenty feet and reduced the grade to 8%, which forced the road to wind back and forth on the side of the Nuʻuanu Pali rather than straight down, but delays due to rain damage and high costs prevented the new Pali Road from opening until 1897 (Thurston 1890:265) (Figure 40). Johnny Wilson, a young engineer with the Public Works Department, spent months surveying the steep terrain and forest of the Pali, but there were difficulties, such as "workers getting dynamited to oblivion and tumbling over the precipice…” (Chiddix and Simpson 2004:78). Construction workers found an estimated 800 skulls, along with other bones at the bottom of the Nu‘uanu Pali—the remains of the warriors defeated by Kamehameha (*Island Call* 1953). The road was declared open in 1897 and was maintained for 55 years with occasional improvements (Figure 41) until work began in 1952 to construct a new four-lane highway with two tunnels running under the *nuku* where Kalanikupule fought Kamehameha’s forces (Devaney et al. 1982:172).

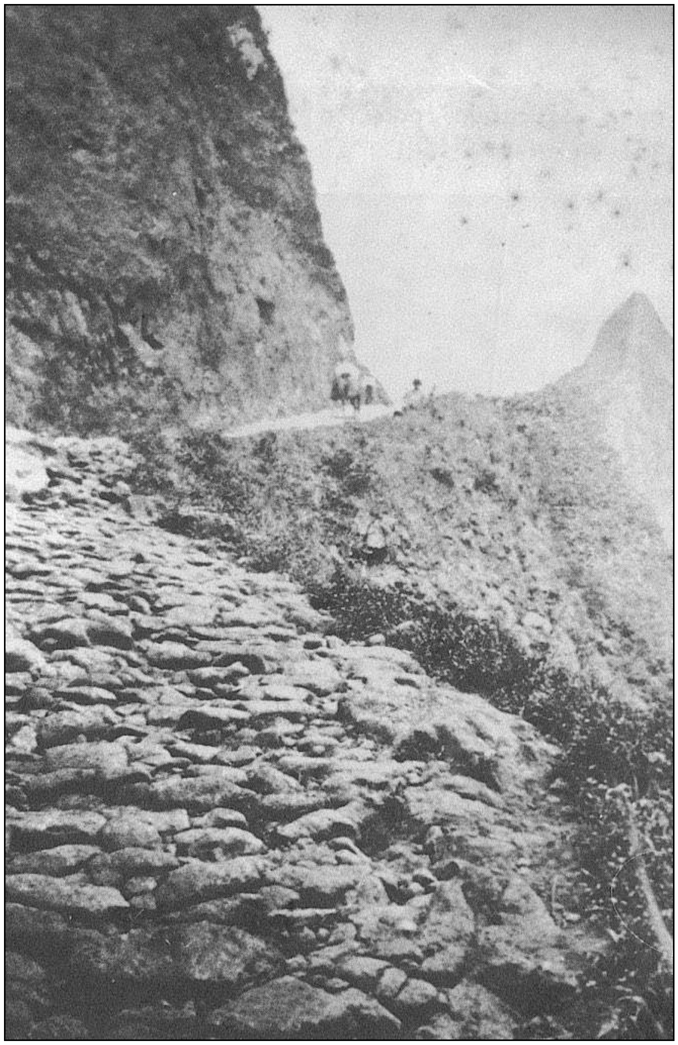

Figure 39. The stone-paved Pali Trail with horses in the background, 1887 (Hawai‘i State Archives, in Devaney et al. 1982:177)

Figure 40. Old Pali Trail (left) and the newly constructed Pali Road with stone wall (right), 1880s (Bernice Pauahi Bishop Museum Collection, in Devaney et al. 1982:175)

Figure 41. Old Pali Road, 1946 (Hawaiian Aviation Preservation Society 2009)

3.3.6 The Māhele

The Organic Acts of 1845 and 1846 initiated the process of the Māhele—the division of Hawaiian lands—that introduced private property into Hawaiian society. In 1848, the Crown and the *aliʻi* received their land titles. *Kuleana* (Native Hawaiian land rights) awards to commoners for individual parcels within the *ahupuaʻa* were subsequently granted in 1850. The Crown Lands were considered the private lands of the monarch, and many lands were sold or mortgaged during the reigns of Kamehameha III and IV to settle debts to foreigners. To end this practice, the Crown lands were made inalienable in 1865, and their dispensation was regulated by a Board of Commissioners of Crown Lands, which effectively put them under the administrative control of foreign-born residents (Kameʻeleihiwa 1992:310). Before the passage of the Act of January 3, 1865, which made Crown Lands inalienable, Kamehameha III and his successors did as they pleased with the Crown Lands, selling, leasing, and mortgaging them at will (Chinen 1958:27).

In 1850, the Privy Council passed resolutions that would affirm the rights of the commoners or native tenants. To apply for fee-simple title to their lands, native tenants were required to file their claim with the Land Commission within the specified time period of February 1846 and February 14, 1848. The Kuleana Act of 1850 confirmed and protected the rights of native tenants. Under this act, the claimant was required to have two witnesses who could testify they knew the claimant and the boundaries of the land, knew that the claimant had lived on the land for a minimum of two years, and knew that no one had challenged the claim. The land also had to be surveyed.

Not everyone who was eligible to apply for *kuleana* lands did so and, likewise, not all claims were awarded. Some claimants failed to follow through and come before the Land Commission, some did not produce two witnesses, and some did not get their land surveyed. Out of the potential 2,500,000 acres of Crown and Government lands, less than 30,000 acres of land were awarded to the Native-Hawaiian tenants (Chinen 1958:31).

Among the first written descriptions of Kāneʻohe Ahupuaʻa by Hawaiians are the testimonies recorded during the 1840s and 1850s in documents associated with LCAs and awardees of the Māhele. As a result of the Kuleana Act of 1850, 242 *kuleana* land claims were made for Kāneʻohe Ahupuaʻa, but only a bit more than half of those were awarded, with the average *kuleana* award constituting about 2.4 acres (Kelly 1976:8). However, these claims were not only for commoners, as chiefs and/or *konohiki* (headmen) were also awarded lots. Kamehameha III had inherited Kāneʻohe and retained the bulk of the *ahupuaʻa* during the Māhele. After his death, these lands went to his wife, Queen Kalama, eleven *konohiki*, and three non-*konohiki* (privileged awardees who received large parcels of land) (Barrère 1994; Kameʻeleihiwa 1992; Kelly 1976:7).

Historic maps indicate that the lands in the vicinity of the Project area were designated as Crown Lands, Government Lands, and Konohiki Lands (Lyons 1876, see Figure 15). The *ʻili* of Waikalua and Paʻalae were designated as Crown Lands and Government Lands, respectively. The *ʻili* of Malae and ʻAikahi were awarded to Queen Kalama (LCA 4452:13), the *ʻili* of Mahinui was awarded to Kapu (LCA 6400), the *ʻili* of Puahuʻula was awarded to Luisa Kealoha (LCA 7587), the *ʻili* of Kalāheo went to Kokoahe (Grant 1106), and the *ʻili* of Keana was awarded to William Harbottle (LCA 2937).

No *kuleana* land claims were awarded near the Kailua WWPT, but testimonies associated with the LCAs reveal that Hawaiians used the land near the Kāne‘ohe WWPTF primarily to grow taro and *kula* crops and built *loko i‘a* along the coast of Kāne‘ohe Bay (Waihona ‘Aina 2000) (Table 1, Figure 42). The coastal flat area between Kanē‘ohe and Kawa Streams immediately *mauka* of the Waikalua Loko Fishpond, known as the Waikalua Swamp and now the site of the Kāne‘ohe WWPTF, was an area of intense production of taro. Claimants who resided in other *‘ili* with less reliable sources of fresh water tended to maintain *lo‘i* in the Waikalua Swamp area as *lele* (a detached part or lot of land belonging to one *‘ili* and located in another) (Waihona ‘Aina 2000).

Table 1. LCAs within the Project Area

LCA #	*ʻIli*	Claimant	Land Use	Awarded
1899	Puʻuiki, Kaluapuhi, Pakui	Opunui	*Loʻi*, house lot	Three *ʻāpana* (lot)
1995	Punaluʻu	Nuole	*Loʻi*, house lot	Two *ʻāpana*
2060	Puʻuiki, Waikalua	Kaulakoa	*Loʻi*, house lot	Four *ʻāpana*
2444	Kalokoai	Keawekukahi	*Loʻi*, fishponds	Three *ʻāpana*
2628	Waikalua	Paele	*Loʻi*, house lot, fishpond	Three *ʻāpana*
2941	Opuʻupao, Kapu, Puaʻai, Punaluʻu	Kekalei	*Loʻi*, house lot	Three *ʻāpana*
3344	Keana, Mikiola, Punaluʻu	Naiwieha	*Loʻi*, house lot, *hala* trees	One *ʻāpana*
3692 B	Waikalua	Keaka	*Loʻi*, house lot	Four *ʻāpana*
3706 B	Kaluapuhi, Keana	Nawai	*Loʻi*	One *ʻāpana*
3707 B	Kaloioai	Keawe	*Loʻi*	One *ʻāpana*
4217	Malae, Waikalua	Kaula	*Loʻi*, house lot, *kula*, fishpond	Four *ʻāpana*
4481	Keana, Waikalua	Honuaiwa	*Loʻi*, house lot, *kula*	Four *ʻāpana*
4486	Mahinui	Kane	*Loʻi*	Four *ʻāpana*
8892	Keana, Puʻuiki, Waikalua	Kumoenahulu	*Loʻi*, house lot	Two *ʻāpana*
9639	Waikalua, Keana, Punaluʻu	Kaniau	*Loʻi*, house lot	Four *ʻāpana*
10202	Puʻupao, Mikiola	Makakea	*Loʻi*, house lot, fishpond	Three *ʻāpana*
10605 (Konohiki Award)	Mikiola	Iona Piʻikoi	(Not stated)	Mikiola ʻIli
10668 B	Mahinui, Mikiola	Oʻopa	*Loʻi*, house lot, *kula*, fishpond	One *ʻāpana*
10739	Kalokoiai	Pa	*Loʻi*, house lot	One *ʻāpana*

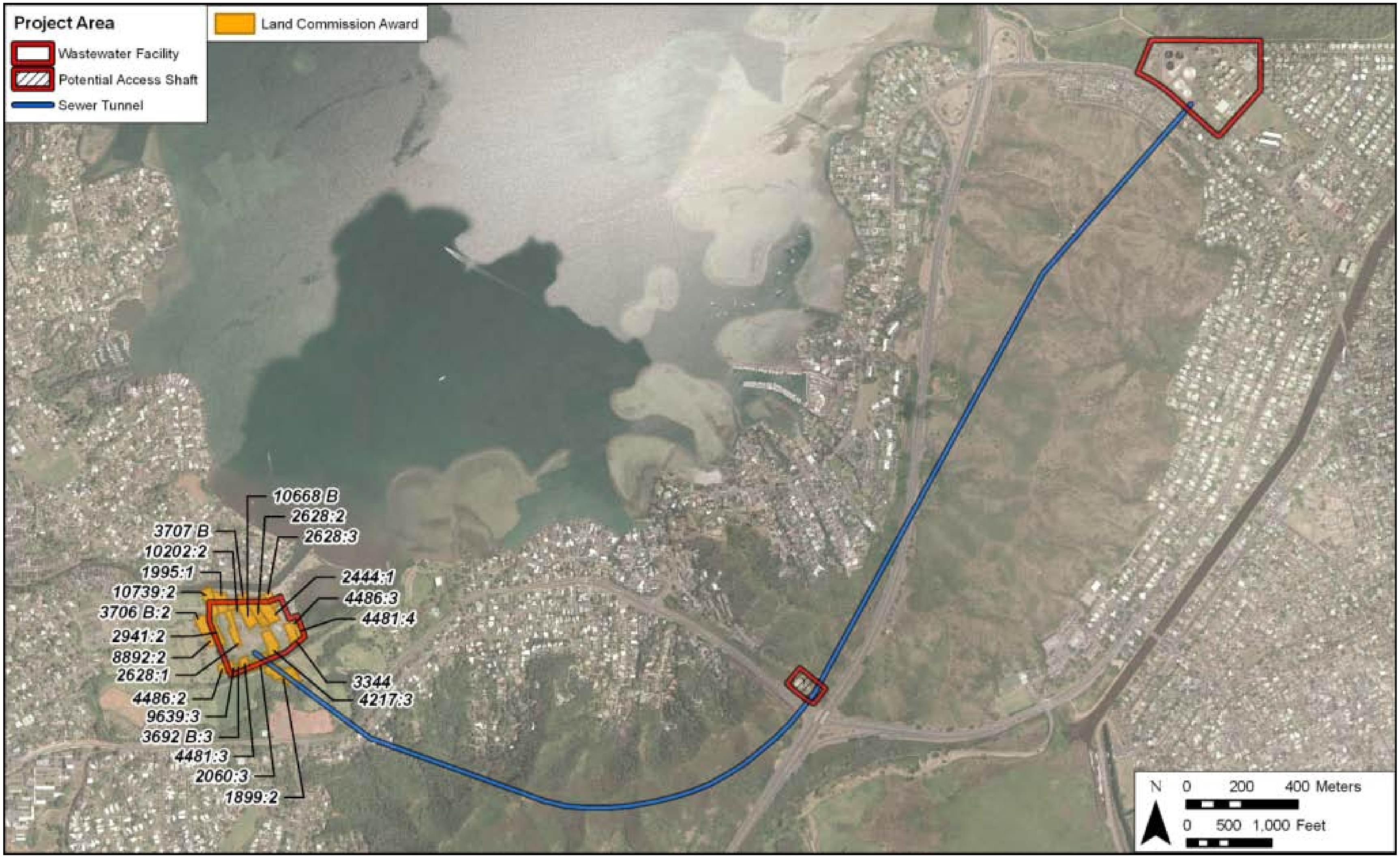

Figure 42. Portion of the orthoimagery of the 1998 USGS 7.5-minute topographic quadrangle showing LCAs in the Project area

3.3.7 Shifts in Agricultural Use of the Land

In addition to the introduction of private and public land ownership laws of the Māhele, Hawaiians of Kāne‘ohe during the mid- to late-nineteenth century experienced land-use shifts from taro production to successive eras of rice, sugar cane, and pineapple cultivation, as well as ranching and dairy industries. Population density estimates for 1853 (Figure 43) show that approximately 700 people lived near the coast of Kāne‘ohe Ahupua‘a, which was one of the more densely populated areas on O‘ahu (Coulter 1931).

Taro remained the dominant crop in the vicinity of the Project area until the 1870s, but the influx of Chinese immigrants and the decline of the Native Hawaiian population forced a shift to rice cultivation. These immigrants used the ancient taro *lo‘i* and *‘auwai* irrigation systems to support their rice cultivation (Figure 44). By the late 1880s, virtually the entire floodplain areas of Kāne‘ohe were under rice cultivation. In 1892, the Kaneohe Rice Mill was erected and put into production on property adjoining Waikalua Stream so that a flume brought water from the river to the rice mill. About twice a week a steamer came into Kāne‘ohe Bay to pick up and transport rice to markets in Honolulu (Allen 1987:295).

Coinciding with the increase in rice production was the advent of commercial sugar cane production in Kāne‘ohe. One of the earliest sugar plantations on O‘ahu was owned by Charles Coffin Harris, who came to Hawai‘i in 1850 with a plan to practice law. He established the Kaneohe Sugar Plantation Company (ca. 1865) on 7,000 acres of Queen Kalama’s land (Dorrance and Morgan 2000:41). In 1871, Harris bought Queen Kalama’s Ko‘olaupoko properties from her heir, Charles Kana‘ina, including the fishponds of Waikalua Loko and Keana (Devaney et al. 1982:29). Harris’s plantation shut down in 1891 because the sugar yield was not enough to support the operation (Dorrance and Morgan 2000:41). Harris’s daughter and heir, Mrs. David Rice, incorporated the lands as Kaneohe Ranch and James B. Castle purchased a large block of her land holdings in 1907 (Dorrance and Morgan 2000:42).

Cattle ranching also became a major industry in Kāne‘ohe during the mid-nineteenth century. The English captain George Vancouver had introduced cattle and sheep to O‘ahu in 1793 (Henke 1929:8) and by the 1840s, cattle had multiplied into a large herd (Devaney et al. 1982:70). At its peak, Kaneohe Ranch extended from the ocean in Kailua to the Nu‘uanu Pali and included 12,000 acres and 2,000 head of cattle (Henke 1929:62). Cattle ranching, as well as horse grazing, in Kāne‘ohe continued into the 1900s (Fiddler 1956:1). Harold K.L. Castle, the only child of James B. Castle, owned most of the *ahupua‘a* of Kāne‘ohe in the early 1900s (Kaneohe Ranch Management Limited 2008). In 1917, he purchased 9,500 acres of land from Harris’s daughter (Henke 1929:62). By the end of World War II, ranching was no longer economically viable for Kaneohe Ranch, and the ranch became primarily a landlord to other farmers (Kaneohe Ranch Management Limited 2008).

The dairy industry rose to prominence over cattle ranching in the post-war years. The shortage of available land due to urban expansion, the shortage of fee-simple land, and the high price of land leases forced farmers in the dairy districts near Honolulu (e.g. Koko Head) to relocate to more remote areas of O‘ahu, including Kailua and Kāne‘ohe (Durand 1959:241). The dairy industry was relatively short-lived as the expansion of the Pali route, exorbitant land prices in

Honolulu, and more automobiles on Oʻahu contributed to rapid urbanization in the *ahupuaʻa* of Kāneʻohe and Kailua (Durand 1959:244–245).

Pineapple cultivation became prominent in Kāneʻohe from approximately 1910 to 1925. The company of Libby, McNeill and Libby built a pineapple cannery in Heʻeia Ahupuaʻa in 1911 and cultivated 2,500 acres that stretched across the *ahupua*ʻa of Kāneʻohe, Heʻeia, and Kahaluʻu (Harper 1972). Kaualaukī Heiau in Heʻeia Ahupuaʻa was mostly destroyed by pineapple field clearance during this time—a likely fate of many archaeological sites (Kelly 1987). While the rice fields that covered old taro lands were mainly located near streams and near the coast, the pineapple fields were located on the slopes of higher lands (Figure 45), usually on land subleased to individual Japanese farmers (Miyagi 1963:115). The pineapple fields were abandoned when Molokaʻi and Lānaʻi pineapple cultivation began to boom. After the cannery closed in 1923 (Dorrance 1998:95), several small farmer families returned to rice cultivation and cattle crazing (Kelly 1975:47).

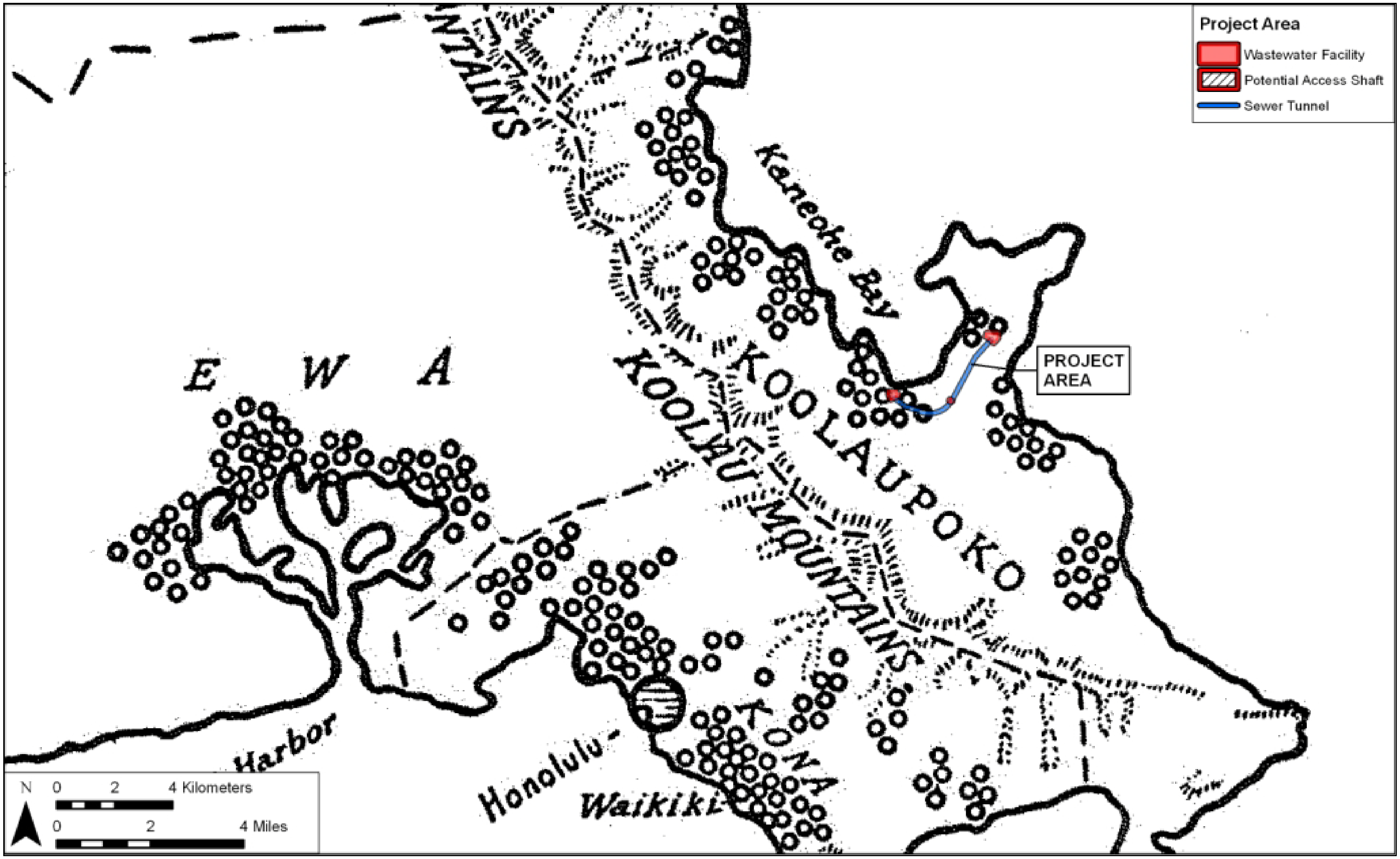

Figure 43. 1853 population density estimates; each symbol represents 50 people (Coulter 1931)

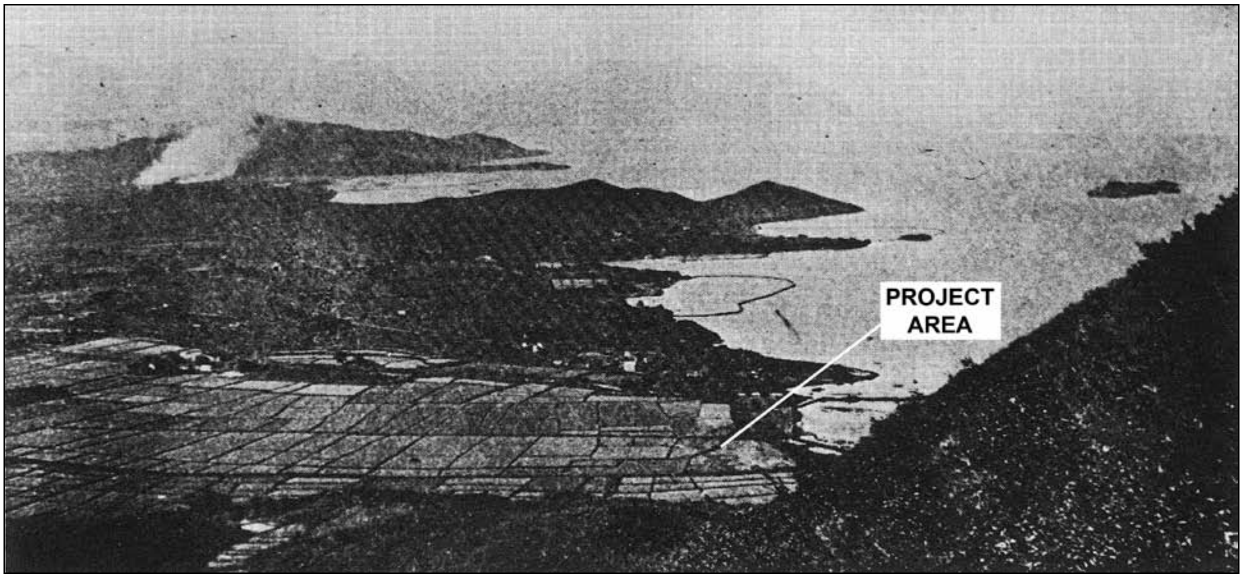

Figure 44. Rice fields in the Waikalua Swamp area circa 1910 (*Mid-Pacific Magazine* September 1913, in Devaney et al. 1982:53), showing the location of the Kāneʻohe WWPTF portion of Project area

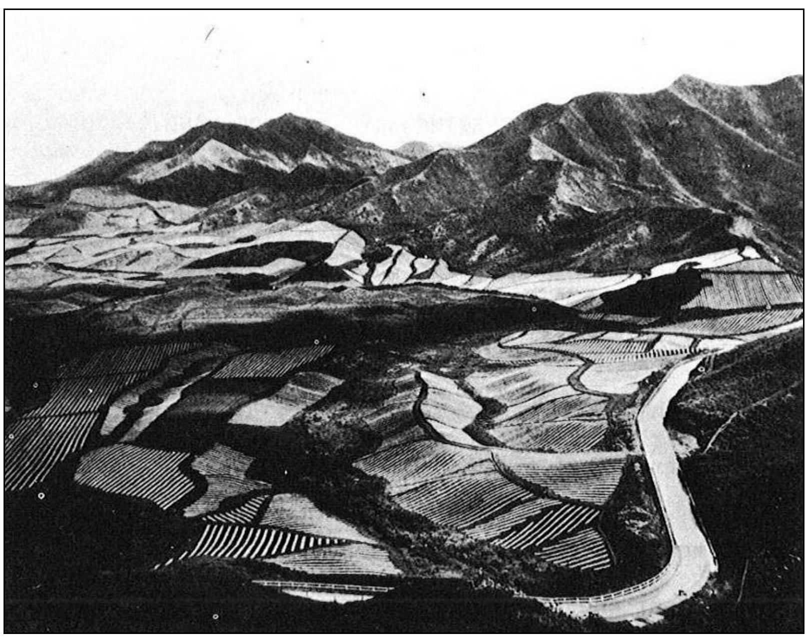

Figure 45. Photograph showing the extent of pineapple cultivation in the *mauka* regions of Kāneʻohe (*Paradise of the Pacific*, in Devaney et al. 1982:69)

3.3.8 Military Infrastructure and Modern Land Use

In 1918, a military reservation called Fort Hase was built on Mōkapu Peninsula. Now known as the Marine Corps Base Hawaiʻi (MCBH), this military infrastructure helped lead to a boom in commercial and residential development in and around Kāneʻohe. Following World War II, the military filled in six fishponds in Kāneʻohe Bay, which provided land for 107 residential lots (Dorrance 1998:95).

Post-war housing demands in Honolulu placed pressure on the infrastructure development of windward Oʻahu (Johnson 1991:359–361). The newly constructed Wilson Tunnel on the Likelike Highway and the expansion of the Pali Highway in the 1950s and 1960s allowed easier access from Honolulu through the Koʻolau Mountains to windward communities, and this led to increased residential development. High tax rates on real estate sales forced many old-time landowners to lease their land to residential developers rather than sell on a fee-simple basis. Kaneohe Ranch at one time leased their land to over 5,000 single family residential lots in the *ahupuaʻa* of Kailua and Kāneʻohe. The vast majority of the leaseholds were sold to the lessees (Kaneohe Ranch Management 2008).

Historic maps show a general lack of development in the Project area until after the early 1950s (Figure 46 to Figure 50). Urbanization and associated improvements (e.g., flood control, road construction, and construction of the Kāneʻohe sewer plant) extensively modified the Kāneʻohe WWPTF portion of the Project area during this period. In 1963, the Kāneʻohe Sewage Treatment Plant and adjacent nine-hole Bay View Golf Course were constructed. Kawa Stream, which formerly flowed into Waikalua Loko fishpond, was channelized in the 1960s and 1970s to flow into Kāneʻohe Bay. Kāneʻohe Stream, which had provided water for *loʻi* and later rice, was also channelized and dammed in the 1970s (Dashiell 1995:9). The sewage treatment plant was converted to a wastewater pump station in 1978, then converted to a preliminary treatment facility in 1994, and upgraded in 1998. The Kailua WWTP was built in 1965 and expanded in 1994 after the ʻAhuimanu and Kāneʻohe treatment plants were converted to preliminary treatment facilities (City and County of Honolulu 2009).

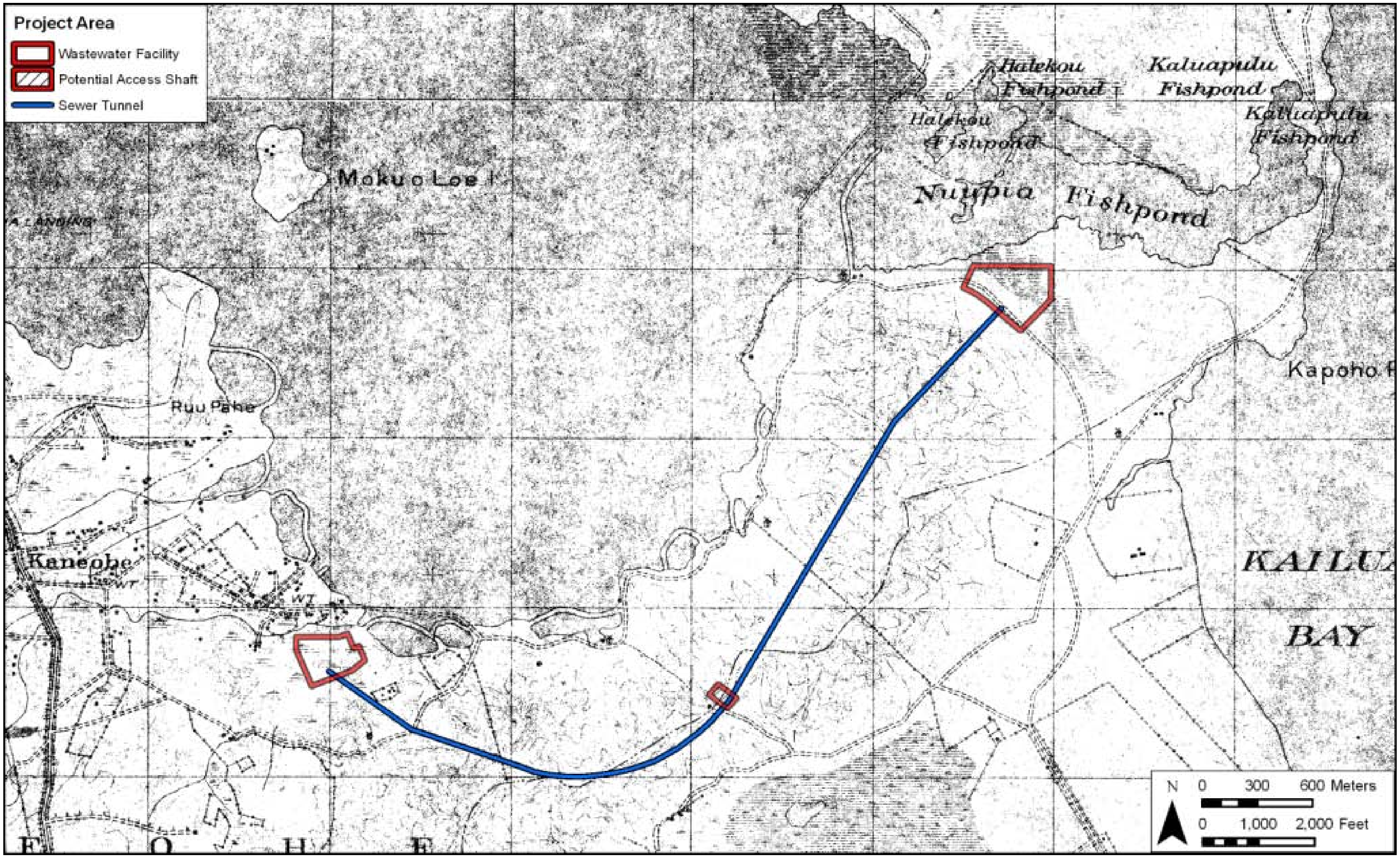

Figure 46. Portion of 1919 U.S. War Department map showing the Project area

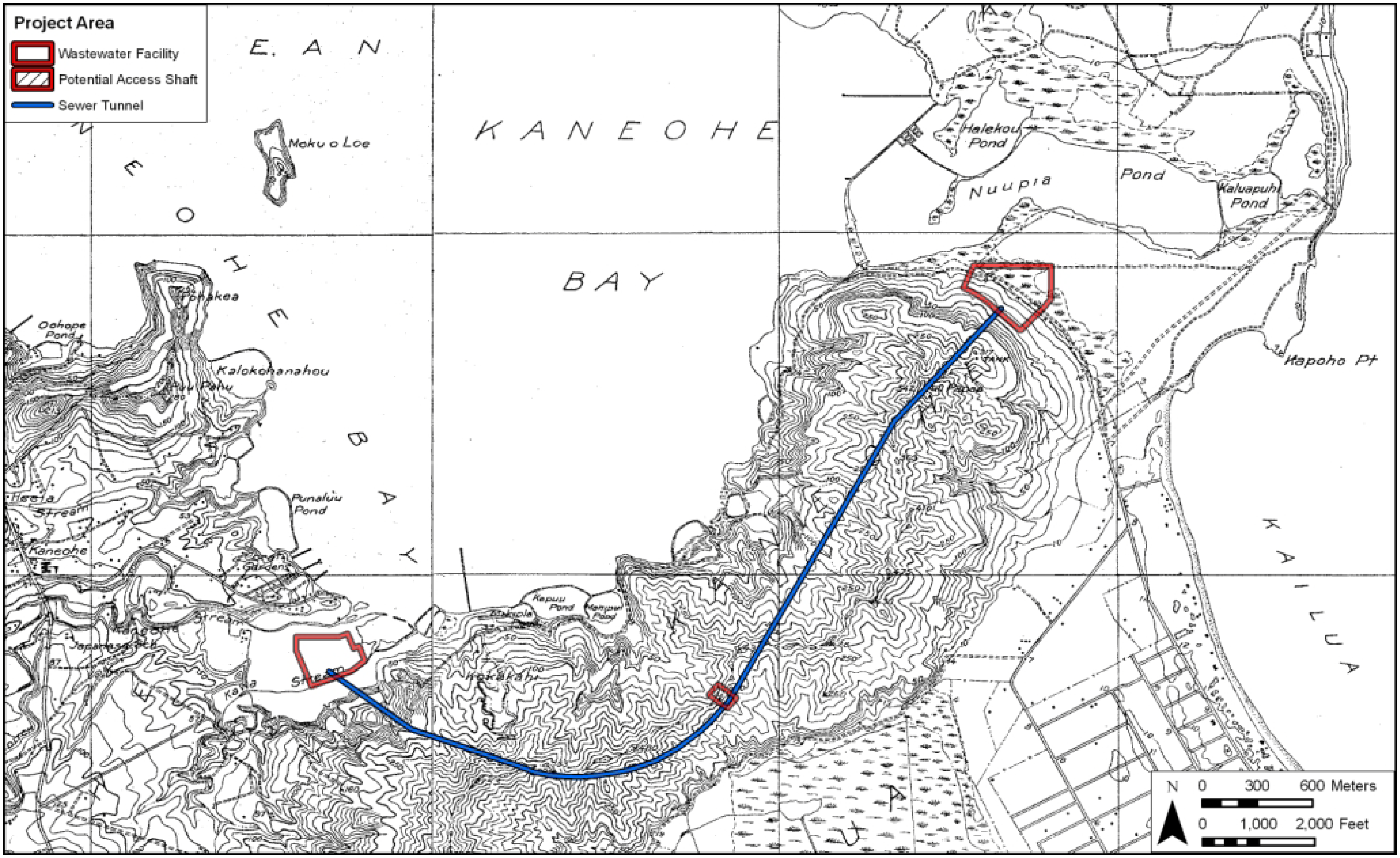

Figure 47. Portion of 1928 USGS 7.5-minute topographic quadrangle showing the Project area

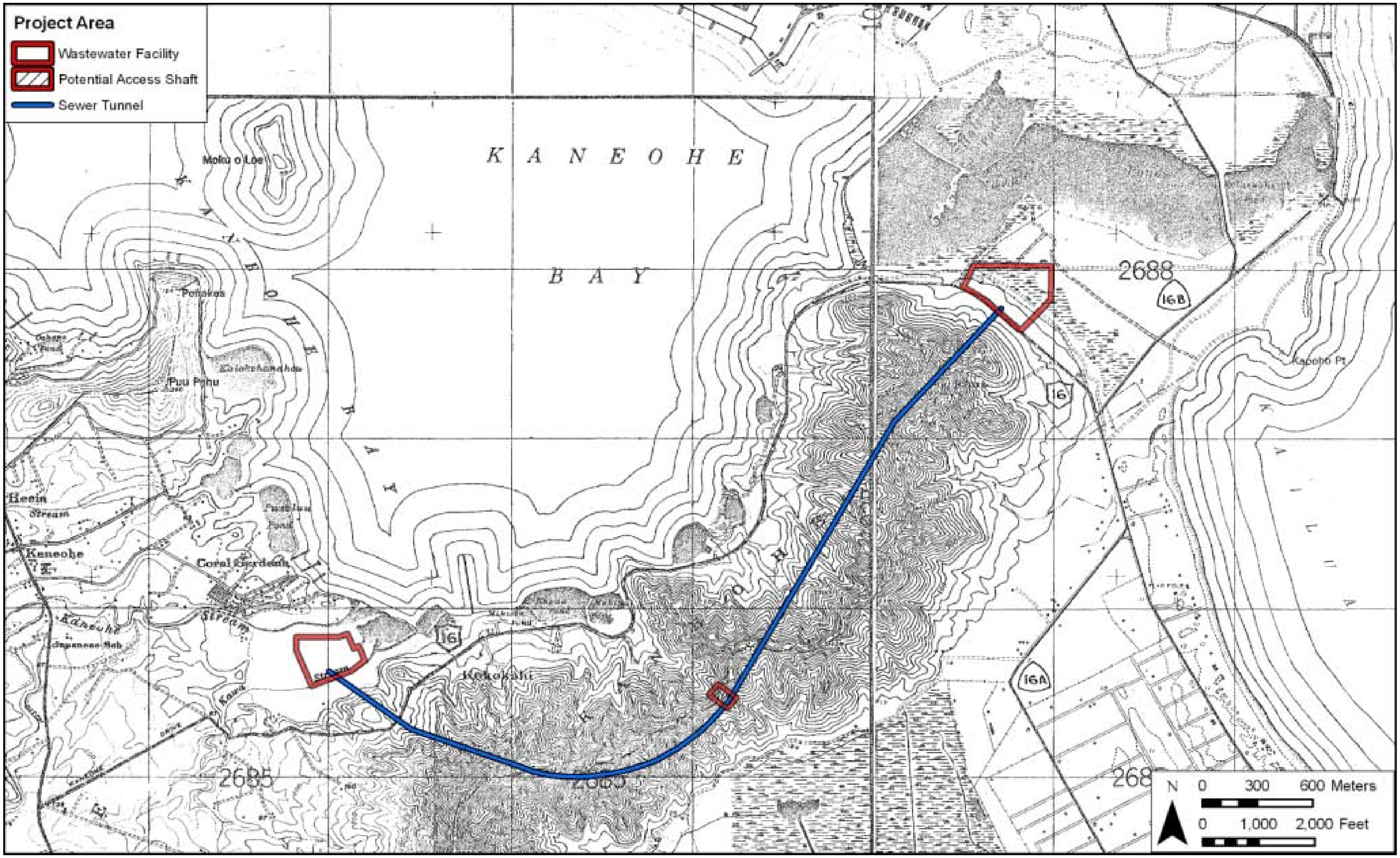

Figure 48. Portion of 1943 U.S. War Department map showing the Project area

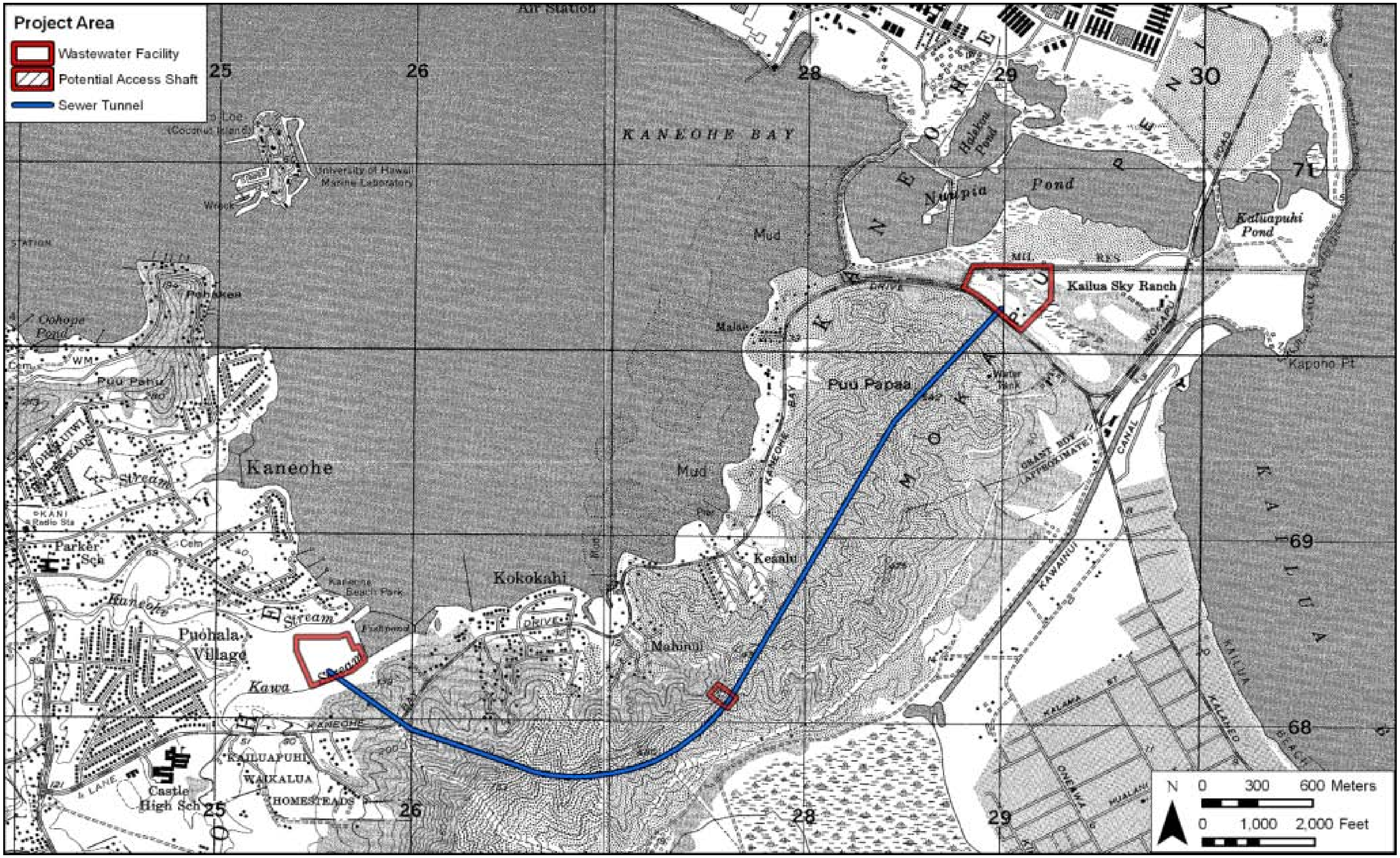

Figure 49. Portion of 1955 U.S. Army Mapping Service map showing the Project area

Figure 50. Portion of the orthoimagery of the 1978 USGS 7.5-minute topographic quadrangle showing the Project area

Section 4 Previous Oral History Research

In 2007, the Koʻolaupoko Hawaiian Civic Club collected oral and written histories of the Kāneʻohe community. As most of the senior residents were of Japanese ancestry, the resulting compilation, *Partial History of the Japanese in Kaneohe 1898 to 1959* (Fanning 2008), celebrates the lives of this distinctive community in Hawaiʻi. This section builds on the previous cultural and historical background by highlighting the voices of two deceased Kāneʻohe residents of Japanese ancestry who grew up in the early twentieth century—Joe Takebayashi (Fanning 2008:82–90) and Kenneth Fusao Wakabayashi (Fanning 2008:94–106). Their stories from past generations color the cultural and historical background of Heʻeia with nuanced recollections and add depth to the information provided by living *kūpuna* and *kamaʻāina* who were recently interviewed by CSH (detailed in Section 6).

4.1 Joe Takebayashi

Joe Takebayashi, born in 1921, grew up in Kāneʻohe at the eastern end of a large fishpond managed by his parents. The following passages highlight Mr. Takebayashi's recollections of fishing throughout Kāneʻohe Bay and utilizing the gates of a fishpond to store their catch:

> Our house was located at the eastern end of a large fishpond that our parents managed. This pond was divided into two sections and used primarily to raise mullets. Mixed with the mullets were other fish such as awa, awa-awa, and barracuda as well as red and white crabs.
>
> When the Samoan crab began to inhabit in this pond, we began to feel uneasy walking inside the pond. One pinch with its claw would have been disastrous.
>
> Dad would take Roger [brother] and me each morning towards the bay near Coral Garden [near Waikalualoko Loop near the end of Waikalua Road] to catch "nehu" which was used as bait for fishing. We would get on his boat, jump inside the cold morning ocean and drag nehu net to catch these tiny nehus. When we were lucky, one scoop with the net was enough to supply us with bait for the day, but some days when nehus scarce we had to spend hours dragging around the bay for them. After we have enough nehus, then we would head for home, change into dry clothes and leave to fish inside Kaneohe Bay the rest of the day.
>
> Mom would have our lunch prepared and around noon when fish were not biting, we would gather around Dad and have lunch.
>
> Fish called "omaka", related to the mackerel species, was the main fish we caught. The hooked omakas were kept alive inside a compartment of our boat. This compartment had holes drilled at the bottom and sides of our boat that allowed sea water to circulate from the outside into this compartment. In this way the omakas were kept alive.

> At the end of the day we would return, pull the boat alongside the fishpond, and scoop the fish from the boat compartment into a gate of our pond. An opening on the wall of the fishpond was built to allow ocean water to circulate between the pond and the ocean. When the tide rises, ocean water would flow into the pond through this gate and when the tide subsides, water would flow out. In other words the level of the pond would rise or lower according to the tide. However, the pond would not lose all the water since the ocean water surrounded the wall of the pond on the outside.
>
> The caught fish would be alive inside this gate. Then the following morning these fish were scooped out of this gate, placed inside a wooden box and taken toward Coral Garden when we went after more nehus. At the beach, a Chinese taxi driver would pick up the box and take it to the fishmarket in Honolulu. This taxi driver was named Mr. Ching and he was very kind to us. Every morning we would make certain that we were at the beach area before him. He would return the empty box of the previous day and give Dad cash from the sale of fish of the previous day. Dad would pay him for cost of handling and transportation. The same thing was repeated every morning we had fish to send to market. (Fanning 2008:82–83)

4.2 Kenneth Fusao Wakabayashi

Fanning (2008:94–106) compiled an oral history of Kenneth Fusao Wakabayashi as told to Michael Okihiro in 1994. Mr. Wakabayashi, born in 1915, remembers that his father used to take care of the pineapple cannery's mules and horses, which powered the cultivation of the pineapple fields before the advent of mechanized technology. The following paragraphs highlight salient passages of this written testimony that pertain to Kāneʻohe Bay and the waters near the Project area, including a community at the Heʻeia waterfront called the Fish Camp:

> I liked fishing and high school age already I started going down. I was dating one girl over there, Matsushima or Fukushima, forgot. Anyway so I go down there and I was friends with Bill Turbin and Shoichi Nakahara. And I get to know the Moritsugu's and Hamano's. I went fishing with them around four or five times. And Mura and his step-father, I think. They had one sampan with a one lung engine. Pok, pok, pok kind. Couple times I went with him.
>
> Night time. Mokapu point side. Those days had a bank of coral, then the rest is all sand, see. So in the sand we go drag net. It was a big net so they used to welcome my help. They dump the net, and four guys on one side and four guys on the other side, they pull until they close the net to the pocket. Was a hard job though. They pull about four or five times I think, and call it a night. But the bay supported them. Weke, palani, all the kind stuff. Plenty too.
>
> From Mokapu, then go way inside where your father had the fish pond. All the area was sand. Then they introduced this black oyster and that filled up everything. I don't know how the bay is now, but when the Marines took over,

they flatten all the landing area, the coral on the side of the mound. Moritsugu Camp had one gang and Kunimura Camp had one gang too. So if the weather was right and the moon phase was right, practically every night they were out there. Kato was hauling fish (to town).

When I got to know your father them well I was with Sadao (Haitsuku) them. We used to go torching. I like fishing so I used to go torching with them. And we used to anchor (at) your house all the time. Then after that Aoki old man used to go down. After the Marines took over Mokapu, that area was off limits. Sadao, me, Mura and Katsuto, the four of us. And when the old man came (Aoki), Ah Lum (Wong) used to go with us. Good fun. Those days your father got involved with Keller, I think Sadao because he used to work for the County. So they used to entertain the City Hall big wheels. So I think once a month like that, the whole gang used to come your house. Your father had two boats. One boat all the guests on top, and then one supply boat in the back. All the whiskey and one keg of beer. Whole weekend affair, that was. Us we did the fishing for the gang. We go catch the fish. Guarantee we used to catch though. So the guys who come, had a good time. Fresh fish. One time turtle too. Right on the boat, they cook ‘em.

1927 or 1928 they bring in the Samoan crab. And then 1932 people started catching them, but that was illegal yet. At that time already, I think 1929, 1930, around there, my brother had one boat and he used to work in town and he make friends in town. They like to go crabbing so I took them out with the boat. Kahaluu side, all around there. I myself never saw one Samoan crab yet you know. And I don’t know what it look like. And these guys that I take out they seemed to know everything about the Samoan crab, you know. So I asked them if you seen one? No. That was funny. But then around 1933, ’34, the thing wen fill up the bay. Anywhere you go had Samoan crab. Big ones too. And if you were barefooted you cannot go in the water. Small ones, all the pinch stay up like that. I never seen so many crabs like that. Right by the side of the fish pond that nobody used to maintain, I go over there. My brother was peddler then already. So he tell me to go catch the crab and he go sell for me. No take me one hours’ time, I fill up the big can and come back, maybe one dozen like that. Then my job for me was to tie them. I no can tie the crab. One night I went, I give up. Today they use the heavy rubber band. You gotta tie them nicely with the pinch like that with the string sticking out so you can carry ‘em with that. The thing was strong though. I no can hold ‘em. Ah Lum, our torching days, after an incident, he said no more Samoan crabs in the boat. One time Sadao catch one and put ‘em in the boat. In the excitement the thing was running around and pinched Ah Lum’s toe. His toe nail came off you know. Came black and blue, just like somebody whack ‘em with a hammer.

Around 1940, the fishing camp had quite a few families. Nakahara, Nishiyama, Hamanao, Moritsugu, Matsushima or Fukushima I don’t know, and then up on the hill had Seino, Igawa. (Fanning 2008:104–105)

Section 5 Community Consultation

Throughout the course of this assessment, an effort was made to contact and consult with Hawaiian cultural organizations, government agencies, and individuals who might have knowledge of and/or concerns about traditional cultural practices specifically related to the Project area. This effort was made by letter, email, telephone and in person contact. The initial outreach effort was started in July 2010. Community consultation was completed in September 2010. In the majority of cases, a letter (Appendix E), map, and an aerial photograph of the Project area were mailed.

In most cases, two to three attempts were made to contact individuals, organizations, and agencies apposite to the CIA for the Project. The results of the community consultation process are presented in Table 2. Written statements from organizations and individuals are presented in Sections 5.1-5.3 below and summaries of interviews are presented in Section 6.

Table 2. Results of Community Consultation

Name	Affiliation, Background	Comments
Ailā, William	Hui Mālama I Nā Kūpuna ʻO Hawaiʻi Nei	July 2, 2010 CSH sent letter July 13, 2010 CSH sent letter by email
Akioka, Kalae	Kupuna, Pūʼōhala Elementary School	July 2, 2010 CSH sent letter July 13, 2010 CSH sent letter by email August 9, 2010 Ms. Ayau replied by email and referred Wali Camvel and Kanekoa Schultz (Kākoʻo ʻOiwi)
Ayau, Halealoha	Hui Mālama I Nā Kūpuna ʻO Hawaiʻi Nei	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
Bridges, Cy	OIBC	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
Burrows, Charles	Ahahui Mālama I Ka Lōkahi	July 2, 2010 CSH sent letter July 13, 2010 CSH sent letter by email
Camvel, Donna and Wali	Koʻolaupoko Hawaiian Civic Club	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
Cayan, Coochie	History and Culture Branch Chief, SHPD	July 2, 2010 CSH sent letter July 13, 2010 Ms. Cayan sent a written response (see Section 5.1). Ms. Cayan referred Aaron Mahi, Cy Bridges, and Mahealani Cypher

Name	Affiliation, Background	Comments
Chang, Dr. Lianne	*Kamaʻāina* of Kāneʻohe	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email July 14, 2010 Dr. Chang referred Charles Burrows
Cypher, Mahealani	President, Koʻolaupoko Hawaiian Civic Club	July 2, 2010 CSH sent letter by email July 13, 2010 CSH conducted interview (see Section 6.2) August 1, 2010 Mrs. Cypher approved interview summary
De Silva, Kihei and Mapuana	*Kamaʻāina* of Kailua	July 2, 2010 CSH sent letter July 13, 2010 CSH sent letter by email
Greenwood, Alice	OIBC	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
Hewett, Alice	Koʻolaupoko Hawaiian Civic Club	July 2, 2010 CSH sent letter July 13, 2010 CSH met with Mrs. Hewett, who gave permission to re-use portions of a previous interview (see Section 6.3)
Kailua Historical Society		July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
Kākoʻo ʻOiwi		August 17, 2010 CSH sent letter by email, specifically asking to forward information to Kaneokoa Schultz
Kaluhiwa, Rocky	Koʻolaupoko Hawaiian Civic Club	July 13, 2010 CSH met with Mrs. Kaluhiwa, who gave permission to re-use portions of a previous interview (see Section 6.4) July 13, 2010 Mrs. Kaluhiwa approved interview summary
Kāne, Shad	OIBC, Nā Koa ʻO Pālehua and ʻAhahui Siwila Hawaiʻi ʻO Kapolei Hawaiian Civic Club	July 2, 2010 CSH sent letter July 13, 2010 CSH sent letter by email
Kaʻuhane, Keola	*Kamaʻāina* of Kāneʻohe	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email

Name	Affiliation, Background	Comments
Kawelo, Hiʻilei	Executive Director, Paepae o Heʻeia	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
Kim, Aldin	*Kamaʻāina* of Kāneʻohe	July 2, 2010 CSH sent letter
Koʻolaupoko Hawaiian Civic Club		July 6, 2010 CSH presented Project information at the Koʻolaupoko Hawaiian Civic Club's monthly meeting
Loo, Clifford	*Kamaʻāina* of Kāneʻohe	July 2, 2010 CSH sent letter
Mahi, Aaron D.	Koʻolaupoko Moku Representative, OIBC	July 2, 2010 CSH sent letter July 13, 2010 CSH sent letter by email July 19, 2010 Mr. Mahi replied by email, stating that he will speak with *kūpuna* at the next monthly meeting of the Koʻolaupoko Hawaiian Civic Club
Mahoe, Chinky	*kumu hula* (hula teacher)	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
McKeague, Kawika	OIBC	July 2, 2010 CSH sent letter by email July 8, 2010 Mr. McKeague forwarded letter to Aaron Mahi, and requested a presentation with the OIBC
Meinicke, Fred Kalani	Professor, Windward Community College	July 2, 2010 CSH sent letter. July 13, 2010 CSH sent letter by email.
Nāmuʻo, Clyde	Administrator, OHA	July 2, 2010 CSH sent letter September 15, 2010 CSH called Keola Lindsey at OHA, who recommended contacting the Koʻolaupoko Hawaiian Civic Club and the Waikalua Fishpond Preservation Society
Ogata, Charlie	*Kamaʻāina* of Kāneʻohe	July 2, 2010 CSH sent letter July 13, 2010 CSH called Mr. Ogata, who stated that he is not familiar with the Project area
OIBC		September 8, 2010 CSH presented Project information to the OIBC

Name	Affiliation, Background	Comments
Pedrina, Rich	Halau Hula ‘O Napunaheleonapua	July 2, 2010 CSH sent letter July 13, 2010 CSH sent letter by email July 14, 2010 Mr. Pedrina responded that he forwarded letter to Teri and Clifford Loo, Hau‘oli Akaka, Chinky Mahoe, Lianne Ching, and Blaine Nohara
Takebayashi, Fred	Waikalua Fishpond Preservation Society	July 13, 2010 CSH sent letter by email July 14, 2010 CSH conducted interview by phone with Mr. Takebayashi, who gave permission to re-use the relevant sections of a previous interview
Wada, Susan	Queen Lili‘uokalani Children’s Center	July 2, 2010 CSH sent letter
Wolfgramm, Emil	Resident of Waiāhole	July 2, 2010 CSH sent letter August 17, 2010 Mr. Wolfgramm sent a written response by email (see Section 5.3), and referred the Kalama family, who were not contacted due to time constraints
Wong, Gordon	*Kama‘āina* of Kāne‘ohe	August 11, 2010 CSH called, but could not leave a message August 17, 2010 CSH called, but could not leave a message
Yanagihara, Roy	Neighborhood Board Chair	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
Yim, Evans	*Kama‘āina* of Kāne‘ohe	July 2, 2010 CSH sent letter July 8, 2010 CSH called and left message
Yong, Lilinoe	*Kama‘āina* of Kāne‘ohe	July 2, 2010 CSH sent letter by email July 13, 2010 CSH sent letter by email
Yoshimori, Grant	Hui O Piko’iloa	July 2, 2010 CSH sent letter July 13, 2010 CSH sent letter by email July 14, 2010 Mr. Yoshimori replied by email, stating that he has nothing to contribute about the Project

5.1 State Historic Preservation Division

CSH contacted Phyllis “Coochie” Cayan, History and Culture Branch Chief of SHPD, on July 1, 2010. In a written response sent to CSH on July 13, 2010 (Figure 51), Ms. Cayan states that SHPD’s main recommendation is that the client engages the affected communities through informational meetings in both Kāneʻohe and Kailua to gather their *manaʻo* regarding inadvertent burial encounters and how the Project may impact gathering and access rights. In addition, the Project may impact sacred cultural sites in the general area and expose sites that have been covered by the current wastewater system. Further, the boring technology may penetrate into unknown cultural resources, including possible burials.

LINDA LINGLE
GOVERNOR OF HAWAII

LAURA H. THIELEN
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

RUSSELL Y. TSUJI
ACTING FIRST DEPUTY

LENORE N. OHYE
ACTING DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

July 13, 2010
Mr. Joe Genz
Cultural Surveys Hawaii, Inc.
P.O. Box 1114
Kailua, Hawaii 96734

Log No. 2010.2534
Doc.No. 1007PC003

Dear Joe Genz:

SUBJECT: KANEOHE 15: A Cultural Impact Assessment (CIA) for the Proposed Kane'ohe-Kailua Wastewater Conveyance and Treatment Facilities Project, Alternative 2-Tunnel Route, Kane'ohe Ahupua'a, Ko'olaupoko District, O'ahu Island. (Multiple TMKs).

Mahalo for the opportunity to comment on a cultural impact assessment for the proposed Kane'ohe-Kailua Wastewater Conveyance and Treatment Facilities Project, Alternative 2-Tunnel Route, Kane'ohe Ahupua'a, Ko'olaupoko District that will cross multiple TMKs. This approximately three-mile long project will be aligned to traverse mostly under the Oneawa Hills range mauka of Kane'ohe Bay Drive.

This is a huge undertaking that should embrace as much of the affected communities in the above ahupua'a. The SHPD recommends that your client have 'public' informational meetings to gather mana'o – at least one in Kane'ohe and one in Kailua. Folks should be encouraged to write in or email you all with their concerns if they are unable to attend and/or prefer to share their mana'o separate from a public meeting format as this is a culturally rich area in resources, mythology and tradition.

Despite the modernization of the area with the existing system, this project will certainly need community outreach on traditional cultural impacts in the area including but not limited to inadvertent burials, continued gathering and access rights, as well as other known cultural and sacred sites that are in the general ahupua'a area. Often there are cultural resources that may have been covered up by the existing system that may be exposed with this proposed project. The department is also concerned with the boring technology that will possibly penetrate unknown cultural resources including but not limited to possible burials.

Some folks to talk story and who may refer you to others about this project's cultural impacts include the following:

1.	Mr. Cy Bridges	OIBC District Representative	Cell: 228-6105	bridgesc@polynesia.com
2.	Mr. Aaron Mahi	OIBC District Representative	Cell: 722-2703	aaronmahi@aol.com
3.	Ms. Mahealani Cypher	Ko'olaupoko Hawaiian Civic Club	Phone: 226-4195	malamapono@aol.com

Any questions please call me at 808.692.8025 or email me at Phyllis.L.Cayan@hawaii.gov .

Sincerely,

P. Coochie Cayan

Phyllis Coochie Cayan
History and Culture Branch Chief

cc: Theresa Donham, Acting Archaeology Branch Chief

Figure 51. SHPD response letter

5.2 Emil Wolfgramm

CSH contacted Emil Wolfgramm on July 1, 2010. In a written response emailed to CSH on August 30, 2010, Mr. Wolfgramm, a resident of Waiāhole Ahupuaʻa to the north of Kāneʻohe, provides insights into the cultural traditions of the region. The following information summarizes Mr. Wolfgramm's emailed response.

Mr. Wolfgramm explains that the denuded landscape of Oneawa Hills resulted from Castle and Cook's operation of Kaneohe Ranch. These ranch lands throughout Kāneʻohe, Kailua, and Mōkapu were then transformed into commercial private fee home development projects. From this background, Mr. Wolfgramm recommends that the Oneawa Hills region should be replanted to its natural condition as a native forest along with a layered coverage of shredded vegetative biomass that will sustainably produce soil. Mr. Wolfgramm points to his nursery operation in Waiāhole Valley as an example of such a sustainable native Hawaiian biome. One *ʻōlelo noʻeau* stands out for Mr. Wolfgramm as iconic for such a restoration: "*Ka ulu koa ikai o Oneawa*," which he translates as "The *koa* grove at the seaside of Oneawa."

Mr. Wolfgramm notes that Kāneʻohe, Kailua, and Mōkapu were once primal fishing resources, and that Native Hawaiians still harvest the sea life in these fishing grounds according to the fishing practices of their ancestors. Mr. Wolfgramm refers the Keohokalole clan, a ranking chiefly line whose ancestors farmed at Kualoa and Mōkapu and fished in Kāneʻohe Bay. He recommends that continual, unbroken traditional fishing and gathering rights be permitted to Hawaiians.

According to Mr. Wolfgramm, the high ranking chief Laʻamaikahiki sailed into Kāneʻohe Bay and established his paramount chief compound at Nāonealaʻa (now Kāneʻohe Beach Park), which he picked for its perfect location for landing his canoes. To improve the anchorage, he ordered a joint public improvement project for his followers. They mined the lava hillocks on Mōkapu and then manually moved the black cinder sands by undertaking over 3000 canoe crossings between Mōkapu and Nāonealaʻa. As a result, they provided a smooth landing place for the king's canoes. Along the shoreline between Mokapu and Nāonealaʻa is Mālaʻe, a peninsula that marks an anchorage for voyaging ships, and provided a suitable landing area and tactics training for Nāonealaʻa marine and army units.

Section 6 Interviews

Kamaʻāina and *kūpuna* with knowledge of the proposed Project and study area participated in semi-structured interviews from July to September 2010 for this CIA. CSH attempted to contact 35 community members and government agency and community organization representatives for this CIA report; of those, 14 responded and four participated in formal interviews. CSH initiated the interviews with questions from the following six broad categories: *wahi pana* and *moʻolelo*, agriculture and gathering practices, freshwater and marine resources, trails, cultural and historic properties, and burials. Participants' biographical backgrounds, comments, and concerns about the proposed development and Project area are presented below.

6.1 Acknowledgements

The authors and researchers of this report extend our deep appreciation to everyone who took time to speak and share their *manaʻo* (thoughts, opinions) with CSH whether in interviews or brief consultations. We request that if these interviews are used in future documents, the words of contributors are reproduced accurately and not in any way altered, and that if large excerpts from interviews are used, report preparers obtain the express written consent of the interviewee/s.

6.2 Mahealani Cypher

CSH interviewed Mahealani Cypher at the office of the Koʻolaupoko Hawaiian Civic Club in Heʻeia on July 13, 2010. Ms. Cypher, born in 1946, refers to herself as a "baby boomer" due to her birth being a product of World War II. Her biological father was stationed on Oʻahu during World War II and left without knowing she was ever to be born. Her grandparents, who she calls Papa and Mama Cypher, subsequently adopted her and her younger sister. They raised the two sisters as their own in Kāneʻohe, where Ms. Cypher has since spent her whole life. She considers them her parents and credits them for sharing their cultural knowledge with her.

Papa Cypher was born in Hāna, Maui, and later moved to Oʻahu. He was a police sergeant and then lieutenant, for the entire windward side of Oʻahu from Makapuʻu to Waimea. Ms. Cypher recalls that everyone knew this man, who weighed over 300 pounds and was over six feet tall. After retiring from the police force, he became a distributor for the *Star Bulletin* on the windward side of Oʻahu. Ms. Cypher recalls driving along the coast when he distributed the newspapers and visiting all the windward *ahupuaʻa*. Ms. Cypher recalls that he always protected the family, but he developed gout and had heart problems and eventually passed away when Ms. Cypher was only six years old.

Mama Cypher was a strong woman—tiny but tough. Her mother was Holokahiki Na-kapuahi, and her father was Lum Ho from Beijing, China. She grew up in Hilo with her father, but when he passed away she moved in with his friend Ah Ping. When she was 12 years old, her Hawaiian family sent her to Kalihi on Oʻahu to live with her sister. Instead of being able to attend school, which she deeply loved, her eldest sister Koiwiloa forced her to be the house servant. So, when she was old enough, she married Papa Cypher at the age of 17 or 18, thereby gaining her independence. They had six children of their own, as well as many foster children that Papa

Cypher brought home. Mama Cypher died in 1983 at 86 years old. Ever since her passing, Ms. Cypher feels that Mama Cypher is with her, a type of *ʻaumakua* (deified ancestor) for her, a protecting spirit making Mahealani feel safe and cared for at all times.

A key part of Ms. Cypher's upbringing was spending time with Mama Cypher and listening to her stories. Due to her granddaughter's asthmatic condition as a young child, Mama Cypher took extra care to watch over her health. This allowed Ms. Cypher to spend more time with Mama Cypher than the other children. Mama Cypher shared with her a great deal of family *moʻolelo*, which Ms. Cypher has preserved in writing. She often went driving with Mama Cypher along the windward coast. Mrs. Cypher's grandmother described its various *ahupuaʻa* as they passed through, and shared stories of the area and the people.

Ms. Cypher's grandparents were rich resources of cultural knowledge, and she has also learned from the *ʻāina* (land) itself by "walking in it and listening." In addition, Ms. Cypher describes experiences with several influential individuals who have continued to shape her knowledge of the land. She met these people while conducting research on the impacts of the proposed H-3 Interstate freeway construction. They suggested new ways of observing and analyzing potential impacts. Her first inspiration was Earl Buddy Neller, a State archaeologist during the 1980s, who Mahealani met in 1982. Buddy helped her to see historical and cultural impacts in addition to environmental impacts. Together, they found a bamboo grove adjacent to the most important and largest *heiau* in Kāneʻohe—Kukuiokāne, which was dedicated to the Hawaiian god Kāne. Finding this bamboo grove close to a famous *heiau* of Kāne shaped her understanding of the meaning of Kāneʻohe. While the conventional *moʻolelo* describes the derivation of the name Kāneʻohe as an angry husband, Ms. Cypher believes that it reflects a more poetic meaning—the "sacred bamboo grove of Kāne."

Ms. Cypher then met Lilikala Kameʻeleihiwa, who, at the time, was a professor of Hawaiian Studies at the University of Hawaiʻi at Mānoa. Ms. Kameʻeleihiwa brought a group of Hawaiian Studies students to Kukuiokāne before it was bulldozed to film it. This footage brought validity to a prevailing notion among Kāneʻohe residents that the H-3 Interstate project was going to significantly impact a *heiau*, and that the *heiau* warranted documentation. Frank Hewett, a *kumu hula* and son of *kupuna* Alice Hewett, also went to Kukuiokāne. He declared it *kapu* (taboo) and cautioned people to care for this and other sacred places. In his words, "If you care for the *ʻāina*, it will take care of you. If you neglect or harm the *ʻāina*, the land will eat you."

Ms. Cypher also met Daniel Yanagida, a Kāneʻohe resident of Hawaiian and Japanese ancestry. Mr. Yanagida lived near Kukuiokāne in an area the family calls Kapalaʻi. On their family property lies Kumukumu Spring, a small pond of fresh water associated with Kukuiokāne Heiau and used for ceremonial purposes. His family has lived there for generations; and his grandmother was a *kahuna* and former caretaker of the Kukuiokāne Heiau. Yanagida told Ms. Cypher that before his grandmother died, she turned over the *kuleana* (duty) of caring for the *heiau* to Daniel. He shared his knowledge of the *heiau* with Ms. Cypher. He verified that it was a large site, and confirmed that the proposed H-3 Interstate was routed right through the middle of it. Mr. Yanagida and Ms. Cypher attempted to inform the State on the significance of the site, but the Bishop Museum, which had been hired to work on the project, maintained that it was an agriculture terrace complex and not a *heiau*. This assertion led the State to continue with the H-3 Interstate project. When the State bulldozed the area, they exposed burial sites and bulldozed large, terraced stone walls that marked the *heiau*. They removed *iwi* that Mr. Yanagida persistently tried to recover for a period of over three months, so as to re-bury them; his grandmother had entrusted him to protect the *heiau* and the many graves contained therein. Daniel described the area as containing as many as a thousand burials. His pleas to the Museum, the State Department of Transportation and OHA were ignored, and many people, including Ms. Cypher, believe that this caused his early death at the age of 41. Mr. Yanagida's wife said the spirits were angry and "wanted a life" because the *iwi* were removed from the *heiau*.

After the bulldozing of the *heiau*, Papa Auwai, a respected healer, issued a statement saying that the State was wrong to destroy the area and build through the cultural site, which was in fact a *heiau*. The H-3 Interstate was built despite the findings and the protests. Ms. Cypher makes reference to the many accidents and strange occurrences on the H-3 Interstate, possibly linking the problems to the history of not honoring important spiritual places such as Kukuiokāne Heiau. Not only does Ms. Cypher see fault in destroying the *heiau*, she also believes that the H-3 Interstate brought unwanted development and growth to the area. She cites a socio-economic impact study prepared for the H-3 project that predicted that with the building of the highway, development would occur that would lead to a number of adverse effects on the local community, and says all of those predictions have since become a reality in the communities from Kāneʻohe to Kualoa.

Ms. Cypher discusses four specific cultural areas that could or will be affected by construction of the proposed Project—Waikalua Loko Fishpond, Nāoneala'a, the ridge separating the *ahupuaʻa* of Kāneʻohe and Kailua, and Mōkapu. First, the caretakers of Waikalua Fishpond are currently not growing and harvesting fish, but there is potential for its full restoration. Construction of the Kāneʻohe Wastewater Pre-treatment Facility, which is located adjacent to Waikalua Fishpond, may delay or even push aside its renewal. Second, Nāonealaʻa, or the sands of Laʻamaikahiki, is located at the present-day Kāneʻohe Beach Park. The famous navigator Laʻamaikahiki landed his canoe there and built three *heiau*. Later, in 1737, after years of war among the islands, their counselors convinced the chiefs to gather at Nāonealaʻa. The entire shoreline of the bay was lined with canoes as the chiefs led a peace-making process. Third, the ridgeline between Kāneʻohe and Kailua Ahupuaʻa has been important in distinguishing the separation of these two communities from ancient times until modern day and is directly affected by the project. Fourth, on the peninsula of Mōkapu, according to Hawaiian *moʻolelo*, is where the first man was created by the gods out of the sands of Mōkapu.

In regards to the proposed Project, Ms. Cypher voices two main concerns regarding the underground wastewater tunnel. Inspired by what she believes the *aliʻi* Mailikukahi would have said 500 years ago, she is concerned about allowing additional population growth in an area already heavily populated, and also seeks better protection for Kāneʻohe Bay. She believes that if the new tunnel system enables more people to live in the region beyond current trends in natural population growth (i.e. among already existing resident families), there would be cultural impacts. She believes that the Kāneʻohe region has reached its maximum capacity to sustain a decent quality of life, stating "Quality of life is already impaired; we don't want it to get worse." She is specifically worried for Native Hawaiians and descendants of the earliest immigrant families if more people were to move into Kāneʻohe. As a result of a larger population, Ms. Cypher sees the possibility of an increase in crime, a decreased connection to natural resources, pressure to develop more in Kāneʻohe and along the northern coast of Koʻolaupoko Moku, more competition for affordable housing, and the loss of land.

Ms. Cypher also firmly believes that Kāneʻohe Bay and its natural and cultural resources must be protected. She is concerned that excavated material will overflow into the bay and adversely impact fishing and clamming areas. To illustrate her concern, she describes that during a power outage or a heavy downpour of rain, wastewater overflows into the bay and makes the fish inedible. Kāneʻohe has already seen a loss of many fishing and clamming areas because of development in the past. According to Ms. Cypher, about two dozen fishponds formerly lined the bay, but most have been lost to development. Kāneʻohe Bay was once a prized area for clamming, gathering shellfish, and crabbing, but now it is impaired by the introduction of silt and sewage. Ms. Cypher's family used to gather crabs from this area and bring them home in big pots for the family. Ms. Cypher mentions that the buildup of silt and sewage could be linked to the former dredging of the bay during construction of the military base on Mōkapu Peninsula, as well as construction on *mauka* lands. Ms. Cypher raises a related concern about access to the bay—increased housing along the coast will exacerbate already decreased access to fishing grounds and gathering places.

6.3 Alice Hewett

CSH spoke with Alice Hewett on June 17, 2010 and previously met her on January 21, 2010 at her home in Kāneʻohe. Mrs. Hewett, now 78 years old, was born in Honolulu on Aug 8, 1931 and has lived in Kāneʻohe all her life. Her father, Frank Kanae, was a fireman in Kāneʻohe and her mother raised their children at home. Mrs. Hewett grew up near the present-day King Intermediate School near Kāneʻohe Bay, and her family also owned lands in the Haʻikū wetlands, also referred to as the Haʻikū Plantation, at the base of the Koʻolau *pali* in Heʻeia Ahupuaʻa.

Mrs. Hewett's family used the river water of Haʻikū to irrigate several acres of *loʻi*. She remembers a constant supply of water for the irrigated taro terraces in Haʻikū. As a child, Mrs. Hewett worked with her siblings to clean and pound the taro with machines into *poi*. She was too young to spend much time in the taro fields, but she reminisces fondly about the central importance of taro to her family. She and her family consumed taro as their staple food. They ate it in a variety of ways for most meals, including *poi*, steamed taro, and taro hotcakes. Her family also sold *poi* to U.S. servicemen in Kāneʻohe during World War II and to the public through vegetable markets in town. In fact, she and her family regularly filled 50 bags of taro each morning. As a young girl in elementary school, Mrs. Hewett sewed one- and two-pound bags of *poi*, which sold for a penny per pound.

The Haʻikū lands were incredibly productive. In addition to the intense cultivation of taro from the naturally irrigated wetlands, the taro patches contained *ʻōpae* (freshwater shrimp) (See Appendix B for scientific and common names of plants and animals mentioned by community participants). Mrs. Hewett recollects using the spine of a coconut palm to collect the shrimp. In addition, the land supported an abundance of papaya, banana, and bamboo. Mrs. Hewett's family was also knowledgeable of several plants used for Hawaiian medicines, and they also gathered *māmaki* (an endemic nettle), the leaves of which were used to make tea. Her family also hunted wild pigs and raised chickens in Haʻikū.

Mrs. Hewett's family fished and hunted for crabs in the waters of Kāneʻohe Bay behind their home near the King Intermediate School. In addition, they had access to the Heʻeia Fishpond. Mrs. Hewett remembers with fondness catching and eating *ʻōʻio* (bonefish) and white crabs.

Mrs. Hewett has witnessed many changes to the land of Kāneʻohe and Heʻeia during her lifetime. She recalls that pineapples covered the *mauka* regions of these *ahupuaʻa*, but this enterprise was not very productive. As a result, rice was also cultivated, but the land was transformed once again with the dairy industry. Dairy farmers of mainly Portuguese ancestry allowed their cattle to graze on much of the land in Kāneʻohe. However, the wet, bottom lands were still used to grow taro. Today, taro in this area is seldom grown, so Mrs. Hewett and the Koʻolaupoko Hawaiian Civic Club are actively trying to rebuild the *loʻi* of Haʻikū.

Mrs. Hewett remembers that several Japanese families once lived near the base of the Nuʻuanu Pali. They were dairy farmers who sold vegetable produce and flowers at stands on the old Pali Road *makai* of the present-day Castle Junction. Mrs. Hewett remembered the vegetable stands of Nishimoto and Kanaka. She also referred to Fanning's (2008:98) *Partial History of the Japanese in Kaneohe: 1898 to 1959* to recall other specific family names—Kawamoto, Kimura, Koreyasu, Kashiwabara, Yamada, Kodama, Murabayashi, Takagawa, Tanaka, Sakamoto, and Wakabayashi. In addition, a military training area called the Pali Camp, or 18 Camp, was located at the base of the *pali* during World War II. Mrs. Hewett recalls leaving St. Anthony's Church in Kailua when Japanese planes flying overhead signaled the start of the Pacific theater of World War II. Several of her relatives were killed when they were returning to Pearl Harbor.

Mrs. Hewett is knowledgeable of a *heiau* in Haʻikū Valley, but she is not aware of any historical, cultural or archaeological sites at or near the Project area.

6.4 Leialoha "Rocky" Kaluhiwa

CSH interviewed Leialoha "Rocky" Kaluhiwa at the office of the Koʻolaupoko Hawaiian Civic Club in Heʻeia on April 7, 2010. Mrs. Kaluhiwa, who was born on November 1, 1943, has deep ancestral connections to the *ahupuaʻa* of Heʻeia. She can trace her family lineage over 200 years, including paternal descent through Kanaʻina, the father of King Lunalilo, and boasts over 300 family members today that reside throughout the *ahupuaʻa*. Her grandparents and parents shared numerous *moʻolelo* of Heʻeia with her as a child and she has resided throughout the *ahupuaʻa*, including Haʻikū Valley at the base of the Koʻolau Mountains and the coastal waters in the immediate vicinity of the current Project area. As a result of her extensive experience and knowledge, Mrs. Kaluhiwa is a leading authority on the history, cultural sites, and cultural practices in the *ahupuaʻa* of Heʻeia.

Mrs. Kaluhiwa's father, Elias Likolaui Jones of Hawaiian, English, and Chinese descent, and mother, Frances Peltier of Canadian-French, Native American Blackfoot, and Portuguese descent, inherited five *kuleana* parcels in Haʻikū Valley. Her paternal great-great-grandfather, Komomua, and great-great-grandmother, Koaʻomoku o Heʻeia (the high chiefess of Heʻeia) were *konohiki* of the *ahupuaʻa*. Her paternal grandfather, Ulysses Jones, was the last *konohiki* of the water system of Heʻeia, as well as the Overseer for the *moku* of Koʻolaupoko under the Territory of Hawaiʻi. Affectionately called the "ten cents attorney" for exchanging his legal services for produce, Mr. Jones maintained an extensive *ʻauwai* as part of his stewardship of the land. He fathered 20 children with his wife, Mary Napoe Akona, who was a midwife and cultural practitioner of *lāʻau lapaʻau* (traditional plant medicine).

The former *ʻauwai* traversed the length of the *ahupuaʻa*. According to Mrs. Kaluhiwa, a stream once flowed at the base of the mountains that extends between the valleys of Haʻikū and ʻIolekaʻa, and from there an *ʻauwai* diverted the flowing water along Haʻikū Road toward St. Ann Catholic Church. From there the *ʻauwai* forked, with one canal flowing toward Heʻeia Fishpond and another flowing toward a fishpond near Yacht Club Street immediately adjacent to the current Project area [most likely the Oʻohope Fishpond]. *Mākāhā* on the *mauka* walls of Heʻeia Fishpond open to the flow of Heʻeia Stream. This creates the proper salinity level for the raising of mullet. Mrs. Kaluhiwa speculates that the second branch of the *ʻauwai* leading to the other fishpond may have performed a similar function. Her grandfather, Mr. Jones, oversaw the maintenance of this vital water system until the development of the Crown Terrace subdivision, which forced his family to relinquish their water rights.

Mrs. Kaluhiwa's childhood memories center on the coastal waters of Kāneʻohe Bay. Her family lived at the corner of Yacht Club Street and Lilipuna Road very close to the current Project area. In the late 1950s, she swam in the coastal waters, often racing with her friends from the yacht club beach to Moku o Loʻe. A neighbor named Vicente Gerona and his wife, who the neighborhood children called "Mullet" for her fishlike agility in the ocean, taught the young Mrs. Kaluhiwa how to spear fish and skin dive. As the military detonated the reefs in Kāneʻohe Bay, she caught numerous fish, including *āholehole* (young stage of the *āhole*, Hawaiian flagtail), *weke* (goatfish), mullet, *awa*, and *manini* (convict tang). One particularly vivid memory of fishing in her childhood stems from an explosion, as she felt the vibrations underwater. She gathered oysters and *ʻōpae lōlō* (brackish-water shrimp) to eat with *poi*. She also hunted a variety of crabs, including *ʻaʻama* on the shore rocks and *haole* (white) crabs and *kūhonu* farther offshore. Mrs. Kaluhiwa reflects that her grandparents were *lawaiʻa* (fishermen); he hunted turtles and could spear while standing on the bow of a boat, and she gathered *limu* (seaweed) and squid on the reefs, including two reefs named Malulina and ʻIole (Rat Reef).

In addition to the marine resources, Mrs. Kaluhiwa's family operated a piggery. Mrs. Kaluhiwa remarks that many children used to die during the first year of life. Consequentially, the *lūʻau* (feast) celebrated the first year of life, and has in recent years extended to high school graduations. As the pig was, and continues to be, of central cultural importance to *lūʻau*, they were in constant demand. Mrs. Kaluhiwa describes the customary method of killing and preparing pigs for the *imu*. To Hawaiians, *koko* (blood) was just as important as the meat or other products of the pig. After stabbing the pig in the neck, the blood is collected and cooked with the cleaned intestines. Then, the hair is shaved and burned before cleaning with boiling water and placing in the earth oven.

Mrs. Kaluhiwa also recollects that her neighbors, the Smith family, grew sweet potatoes on one acre of land, while her extended family cultivated extensive *loʻi kalo* near Heʻeia Fishpond. A promontory at the northern end of Heʻeia Fishpond, now the Heʻeia State Park, was a *leina*, a place where souls went for judgment, and this area divided the *ahupuaʻa* into Heʻeia Uli and Heʻeia Kea. Mrs. Kaluhiwa speculates that the name Heʻeia Uli may refer to the dark, deep mud of the area, which her family cultivated to grow taro. The region also has many sinkholes, which, according to Mrs. Kaluhiwa, is possibly where the dark souls went. This assertion stems from an incident in which her uncle as a child fell into a sinkhole and was saved by people nearby. Mrs. Kaluhiwa shares several historic photographs taken in the 1920s of the extensive taro and rice fields near Long Bridge by Heʻeia Fishpond, disagreeably called "stink bridge" after the overwhelming stench of rotting taro. Mrs. Kaluhiwa notes that the remnants of two *poi* mills remain, which she and her family called "hoi" after the *loʻi* of Heʻeia. Now, Mrs. Kaluhiwa, under the auspices of the Koʻolaupoko Hawaiian Civic Club, is spearheading an initiative to restore the *loʻi kalo* of her childhood.

Mrs. Kaluhiwa shares two *moʻolelo* of the coastal waters of Kāneʻohe Bay at Heʻeia Fishpond:

> There's a story about a shark there. There was a woman who gave birth to twins, one child human and one child shark. They used to go to the shoreline to make sure the baby ate.
>
> Of course there is Meheanu, the eel. Part of the time she's eel, part of the time at certain parts of the year she's *moʻo* [water spirit, lizard], the lizard…Certain time of the year, she'd be an eel. And I guess when the *hau* bloomed in certain times of the year, she becomes a *moʻo*…She's also the *ʻaumakua* for the Heʻeia Fishpond…Little baby eels circle the place inside the whole fishpond…My husband one time went fishing. He said there was something so big in the water, it was longer than his boat. Really big, the net could not hold it. They looked in the water and one of his friends said it was the biggest eel he had ever seen. My husband said "don't poke it! Leave it alone!" His friend poked it right at the top of the head. My husband said that the eel twisted and bent that spear. His friend flew off the boat. They never caught the eel. Another time they heard splashes, had their nets out, and said, "All right, catching a big school." When they got up closer to it, it was a ball, a huge ball of eels, intertwined with each other, splashing. Says he never seen that before…It was between the fishpond and the river [Heʻeia Stream].

The upland valley of Haʻikū and the surrounding mountains also figure prominently in Mrs. Kaluhiwa's recollections of her childhood. Just prior to her birth, her father helped to build the Naval Radio Station in Haʻikū Valley, commonly referred to as the Omega Station, one of eight stations worldwide used for radio navigation. The U.S. Coast Guard granted access to Mrs. Kaluhiwa and her family to use the valley for traditional cultural practices, including the gathering of medicinal plants. Mrs. Kaluhiwa remembers gathering *ʻōlena* (turmeric) to treat ear aches and *māmaki*, which is consumed as a medicinal tea. Unfortunately, *māmaki* has been overharvested in recent years, which, according to Mrs. Kaluhiwa, goes against the traditional protocols to plan ahead for seven generations of medicinal plant use. In addition, the community often gathered in a gulch below the Omega Station where a person would stand atop a massive boulder to share *moʻolelo*.

Mrs. Kaluhiwa's father was intimately familiar with the mountain ridges. He and his brothers and a cousin guided military personnel throughout the mountains in search of locations for the cable car for the Omega Station. Mrs. Kaluhiwa also recounts a *moʻolelo* about a cave named

Kaualehu high on the ‘Ioleka‘a mountain cliffs. This family burial cave contains a canoe laden with *iwi*, which her father saw firsthand when escorting military personnel along the cliffs. From the vantage point of the valley, the cave appears to be inaccessible; however, one of Mrs. Kaluhiwa's cousins remembers that a rope made of *hau* used to hang from the opening.

Another poignant childhood memory is the use of flowers from *puakenikeni* (perfume flower), *pīkake* (Arabian jasmine), and *pakalana* (Chinese violet) trees to fragrantly incense the family's outhouses. With the development of the Alii Shores neighborhood, however, Mrs. Kaluhiwa's family and her neighbors were forced to relocate. Mrs. Kaluhiwa left Hawai‘i in 1955 and when she returned four years later in 1959, she was shocked at the scale of development that had taken place, including the completion of the Pali Tunnel and the development of the Likeke Highway. Mrs. Kaluhiwa has since gathered support from her *‘ohana* (family) and community to prevent the construction of a nuclear power plant in He‘eia Kea and the filling of He‘eia Fishpond for major development.

Mrs. Kaluhiwa recalls several cultural sites in the vicinity of the Project area. A fishpond was once located near her home at the corner of Yacht Club Street and Lilipuna Road. From the vantage point of a Chinese cemetery, Mrs. Kaluhiwa recalls seeing a small fishpond, which private owners used during her childhood in the 1950s. In addition, she swam in a stream-fed pond named Makawiliwili and played in an underwater cave in an area that has since been developed into the Crown Terrace subdivision.

Mrs. Kaluhiwa's primary concern of the current Project is that it will promote more development in the region, which will adversely affect the livelihood of Native Hawaiian families.

6.5 Fred Takebayashi

CSH spoke with Fred Takebayashi, the younger brother of Joe Takebayashi (see Section 4.1) on July 13, 2010 and previously met with him on December 1, 2008 at the Waikalua Loko Fishpond in Kāne‘ohe. Mr. Takebayashi, now 83 years old, was born February 9, 1927 to Makita and Kiya Takebayashi at their home in Kāne‘ohe. He is a volunteer for the Waikalua Loko Fishpond Preservation Society that cares for and maintains the Waikalua Loko Fishpond and its surroundings. Due to his father's teachings about fish cultivation at their own fishpond called Mikiola Loko, Mr. Takebayashi is considered an expert in Hawaiian fishpond cultivation. After graduation from high school, he was recruited by the He‘eia Loko Fishpond Society to help restore their fishpond. He spent four years assisting their team to turn the fishpond into a successful fishery operation.

Mr. Takebayashi's family lived on Mikiola Drive east of the Waikalua Loko. His father was the caretaker for the Mikiola Fishpond, which was later filled in 1937 by Walter Dillingham's Hawaiian Dredging Company at the request of the land owner, James B. Castle Estate. Mr. Takebayashi describes what life was like while living on the Mikiola Fishpond:

> My dad, Mikita, was the caretaker for the Mikiola Loko. He was living in Pā‘ia, Maui when he heard of the available lands for lease at the Mikiola Loko. So he raised our family there. I had three sisters and two brothers. As a family we raised fish, mostly mullet, at the fishpond and we also did small farming on our land,

> mostly for sustenance. Sometimes when we had good crops, such as green beans, we would sell to the markets.
>
> The fishpond we had was actually three ponds, one big one in the middle and two smaller ones on the outside. The smaller ones were used as *keiki* or *pua* ponds. *Keiki* or *pua* means the baby fish. We would scoop up the baby mullets from the [Kāneʻohe] bay and put them in the *keiki* ponds until they get bigger. Once they get a certain size, we move them to the bigger pond until they reach the size big enough for harvesting.

Mr. Takebayashi was asked about his early association with the Waikalua Loko Fishpond and its environs:

> I remember as a child, my dad would take us [to] school [Benjamin Parker Elementary School] from the Mikiola Fishpond and we would pass by the Waikalua Loko Fishpond and get dropped off at Kāneʻohe beach park. We would walk to school at Benjamin Parker School. It's an elementary school now but before, it went all the way up to high school. I graduated from there. Anyway, after school we had to go to Japanese school, too. The Japanese school was located right where the Kāneʻohe Medical Building is now. From there, we would walk back down to the beach to look for my dad and the boat. Sometimes he would be there and sometimes he wouldn't. If he didn't come to pick us up, we had to walk back up the hill and cross the bridge over Kāneʻohe Stream, then we would cross the Waikalua [Loko] Fishpond wall and continue to our house at the Mikiola Fishpond. I remember the family that used to be the caretakers for the Waikalua [Loko] Fishpond, it was the Nagamatsu family. Their mullets were bigger than the ones we used to harvest. I think it was because we didn't have a fresh water stream entering our fishpond. They had both the Kāneʻohe and Kawa Streams going into the Waikalua Loko Fishpond and I think it had nutrients from the streams that we didn't have and that's why theirs got bigger.

On Sunday, December 7, 1941, the Japanese bombed the Pearl Harbor Naval Base and other military targets throughout Hawaiʻi, including the MCBH in Kāneʻohe. Mr. Takebayashi recalled the events of that historic day:

> I remember in 1937, the land owner of Mikiola Fishpond, the James B. Campbell Estate, told my dad that they were going to fill in the Mikiola Fishpond so we had to move. We ended up moving *mauka*, kind of across the main street [Kāneʻohe Bay Drive] from where we lived. My dad found some land up there available for lease. So we moved there and began farming things like papaya and other vegetables. So we had a nice view of Kāneʻohe Bay. On Sunday, December 7, 1941, we were outside picking papayas. Sundays and Wednesdays were our papaya picking days because we would take them to the markets on Mondays and Thursdays. So we were outside and we saw these two planes flying towards us and they banked a turn right above us and headed for the marine base [Marine CBH] and I remember saying to my dad "wow, they painted the red Japanese flags on our airplanes for simulation or training purposes." We watch as these two

> planes began to drop bombs on the five military sea planes parked in the [Kāneʻohe] bay. I remember think[ing] how realistic the military training was. My dad told everyone to get in the house and warned us that this was no exercise, this was war. We watched from our house and after the two planes headed back out to sea, another group of Japanese planes came towards the [Kāneʻohe] marine base and began bombing the place. The Marines were returning fire from the ground. I don't think the Marines were able to get any planes airborne. After the wave of attacks from that group ended, they headed back to sea and we saw one of the Japanese planes leave the formation and turn back towards the [Kāneʻohe] marine base. It headed straight for the hill on the base and crashed right in to the hill. It was a *kamikaze* [Japanese for 'divine wind'] pilot. He just smashed into the hill.

During the World War II period in the early 1940s, many Japanese citizens were taken to internment camps, located throughout the State of Hawaiʻi, as prisoners of war. Mr. Takebayashi was asked if he or his family were ever subjects of these internment camps:

> Well the [Government authorities] came to our house a couple of times and I think they felt we were insignificant farmers out here in the country. They felt we posed no threat on a papaya farm. But I remember there were these two fishing camps in Kāneʻohe. One was the Nishiyama camp and the other was the Kunitake camp. They were like competitor fish camps. Anyway, Mr. Nishi [Nishiyama] had this thing about every morning; he would bow to the East as the sun rises. Because he did this bowing thing every day, the authorities took him in custody and sent him to a mainland Japanese internment camp. I think he was one of two people from the Kāneʻohe area to go to those prison camps. Later, I remember one of the kids from the Nishi camp married one of the kids from the Kuni [Kunitake] camp and they became friendly towards each other after that.

Mr. Takebayashi is not aware of any historical, cultural or archaeological sites at or near the Project area, and does not have any concerns or recommendations.

Section 7 Cultural Landscape

Discussions of specific aspects of traditional Hawaiian culture as they may relate to the Project area are presented below. This section integrates information from Sections 3-6 in order to examine cultural resources and practices identified within or in proximity to the Project area in the broader context of the encompassing Kāne‘ohe landscape.

7.1 Settlement

The early settlers of the Hawaiian archipelago would have been attracted to the windward *moku* of Ko‘olaupoko on O‘ahu, especially the specific *ahupua‘a* of Kāne‘ohe, with its coral reefs, bays, and inlets for fishing, dense basalt dikes for the production of stone adzes and other tools, and amphitheatre-like basins and broad alluvial floodplains that contained fertile soils, permanently flowing streams, and high rainfall for the cultivation of crops (Kirch 1985:69). Archaeological sites along the windward coast, from the *ahupua‘a* of Kāne‘ohe to Waimānalo, contain some of the earliest documented Hawaiian settlements (Allen 1987:265; Kirch 1985:69–80). An archaeological site in close proximity to the Kāne‘ohe WWRTF contains a vast assemblage of lithic artifacts radiocarbon dated to A.D. 1070–1405, which suggests that this area housed craftsmen specializing in the production of adzes and other stone tools (Clark and Riford 1986). Archaeological sites at Nu‘upia Fishpond adjacent to the Kailua WWTP similarly contain basalt tools, adze blanks, and flakes associated with stone tool manufacture (Hammatt et al. 1985; Jackson et al. 1993). Very few marine shellfish midden were recovered archaeologically, which suggests that Hawaiians once lived near the fishpond on a temporary or periodic basis (Jackson et al. 1993:78).

7.2 Cultivation and Gathering

The settlers’ descendants developed *lo‘i kalo* and other forms of agriculture in Kāne‘ohe Ahupua‘a, including the cultivation of *‘uala*, *uhi*, *mai‘a*, *hala*, *wauke*, *ōlonā*, and *‘awa* (Handy and Handy 1972:456). Recent archaeological surveys near the Kāne‘ohe WWRTF documented a taro terrace (Clark and Riford 1986) and subsurface agricultural soil indicative of taro production (Hammatt and Borthwick 1989). Land Commission claims, testimonies, and awards of the Māhele reveal that Hawaiians continued to use the land in Kāne‘ohe in the vicinity of the Kāne‘ohe WWRTF to grow *kalo* and *kula* crops of sweet potatoes (Waihona ‘Aina 2000). Successive eras of commercial rice, sugar cane, and pineapple farming transformed the land of Kāne‘ohe Ahupua‘a; the *lo‘i kalo* were converted to rice paddies and sugar cane fields, and *mauka* regions were cleared for pineapple fields (Kelly 1987). Yet, Mrs. Hewett and Mrs. Kaluhiwa recall the intense productivity of surviving taro fields during their childhoods in the *mauka* lands of Ha‘ikū and the *makai* lands near He‘eia Fishpond, respectively. Now, under the auspices of the Ko‘olaupoko Hawaiian Civic Club, they are spearheading an initiative to restore these vast *lo‘i kalo*. Mrs. Hewett and Mrs. Kaluhiwa also recount how their families gathered plants for Hawaiian medicines, such as *‘ōlena* and *māmaki*. Mrs. Kaluhiwa also alludes to the need to have gathered *hau* in order to gain access to a family burial cave high on the ‘Ioleka‘a mountain cliffs by climbing a *hau* rope. She also shares a poignant childhood memory of using flowers from *puakenikeni*, *pīkake*, and *pakalana* trees to fragrantly incense her family's outhouses.

7.3 Marine and Freshwater Resources

The descendants of the Koʻolaupoko settlers also built at least 30 *loko iʻa* in the brackish waters of Kāneʻohe Bay for the harvesting of *ʻamaʻama*, *awa*, and other fish (Devaney et al. 1982:114, 143–144; Summers 1964:2). Three fishponds extended into the bay near the Kāneʻohe WWPTF (Waikalua Loko, Waikalua, and Loko Keana) (McAllister 1933:176) and three fishponds once separated Mōkapu from the main land near the Kailua WWT (Nuʻupia, Kalehou, and Kaluapuhi (McAllister 1933:184). Previously recorded oral histories with Kenneth Fusao Wakabayashi (Fanning 2008:94–106) and Joe Takebayashi (Fanning 2008:82–90), as well as an interview with his surviving younger brother, Fred Takebayashi, reveal how descendants of Japanese immigrant families fished and hunted crabs throughout Kāneʻohe Bay in the early 1900s along the waterfront in community "camps." Mrs. Kaluhiwa remembers catching *ʻamaʻama*, *weke āholehole*, *awa*, and *manini*, gathering *ʻōpae lōlō* and oysters, and hunting a variety of crabs, including *ʻaʻama* on the shore rocks and *haole* crabs and *kūhonu* farther offshore. In addition, Mr. Fred Takebayashi remembers how his father and another Japanese family raised mullet in Mikiola Fishpond and Waikalua Loko Fishpond, respectively. Mrs. Hewett also recollects how she caught *ʻōʻio* in Heʻeia Fishpond, as well as *ʻōpae* in the taro fields.

7.4 Wahi Pana and Moʻolelo

Kāneʻohe Ahupuaʻa contains numerous *wahi pana* and associated *moʻolelo* that place the specific Project area within a broader cultural context. One *moʻolelo* in particular illuminates the entire landscape of the *ahupuaʻa*, from the mountain peaks (Keahiakahoe) and upland forests (Puʻu Kahuauli) to the coastal waters (Puʻu Pahu) and offshore islands (Moku o Loe) by chronicling a sibling rivalry (Hawaiian Ethnological Notes ms. Vol. 2:2181, cited in Sterling and Summers 1978:206; Landgraf 1994:94). Several *wahi pana* are located on lands above the subsurface Project corridor along the Kāneʻohe Bay shoreline, including the *ʻili* of Waikalua, Keana, Mahinui, Kalāheo, Paʻalae, Pūʻahuʻula, Mālaʻe, and ʻAikahi (Lyons 1876; Wall 1914). Most of these traverse Oneawa Hills, a ridge that was named in 1971 after a land division in Kailua (Pukui et al. 1974).

Several *wahi pana* are located in the vicinity of the Kāneʻohe WWPTF and the Kailua WWTF. Waikalua Loko Fishpond, located immediately *makai* of the Kāneʻohe WWPTF, measures over 1,400 feet in length and contains four *mākāhā* (McAllister 1933:176). Laʻa, a navigator from Kahihi—the ancestral homeland of Hawaiians and other Polynesians—arrived nearby on the north side of the mouth of Kāneʻohe Stream, which was called Nāonealaʻa and is now Kāneʻohe Beach Park (Kamakau 1867; Thrum 1916:90). Mr. Wolfgramm adds to this *moʻolelo* that Laʻamaikahiki ordered his followers to mine the black cinder lava on Mōkapu and then transport the sands by canoe to Nāonealaʻa in order to provide a smooth land place for his canoes, a feat that required over 3000 crossings of Kāneʻohe Bay. Mr. Wolfgramm also notes that Mālaʻe, a peninsula along the Kāneʻohe shoreline, provided a suitable landing area and tactics training for Nāoneala‘a marine and army units, and currently marks an anchorage for voyaging ships.

In the twelfth century, the *ali‘i* ‘Olopana erected the massive structure of Kāwa‘ewa‘e Heiau, located about one mile east of the Kāne‘ohe WWPTF, to sacrifice the pig demigod Kamapua‘a (Kalākaua (1990:142–147; McAllister 1933:179; Thrum 1916:90). Nu‘upia Fishpond, located immediately north of the Kailua WWTF, and two adjacent fishponds (Halekou and Kaluapuhi) once separated Mōkapu from the main land of Kāne‘ohe (McAllister 1933:184).

7.5 Ala Hele

The most impressive *ala hele* in the *ahupua‘a* of Kāne‘ohe formerly traversed the sheer cliff rocks of the Nu‘uanu Pali to the base of the mountains. Hawaiians used this steep path to transport taro, *poi*, potatoes, chickens, goats, and pigs from windward O‘ahu to Honolulu (Thrum 1901:89). Kamehameha III, in response to agricultural development in Kāne‘ohe and other *ahupua‘a* on windward O‘ahu, secured funds in 1845 to make the trail accessible to horses by paving the path with stones. In 1882, construction began to widen and reduce the grade of the road. The improved Pali Road opened in 1897 after workers found an estimated 800 skulls along with other bones at the bottom of the Pali—the remains of the warriors defeated by Kamehameha in 1795 (The Island Call 1953). The road was maintained for 55 years until work began in 1952 to construct a new four-lane highway with two tunnels running under the site of the Nu‘uanu battle (Devaney et al. 1982:172).

7.6 Ilina

On the leeward half of Mōkapu Peninsula in Kāne‘ohe Ahupua‘a, excavations in the mid-twentieth century unearthed over 1000 *ilina* (Kirch 1985:111). The Mōkapu sand dunes were most likely established burial grounds for the residents of several villages located on the windward half of the peninsula in He‘eia Ahupua‘a (Sterling and Summers 1978:217). A limestone cobble pavement close to the northern boundary of the Kailua WWTP may cover a burial (Jackson et al 1993), but there is no documented evidence from archaeological surveys, historical records, oral traditions, or interviews of *ilina* or *iwi kūpuna* within the Project area.

Section 8 Summary and Recommendations

CSH undertook this CIA at the request of Wilson Okamoto Corporation. The cultural survey broadly included the entire *ahupuaʻa* of Kāneʻohe, and more specifically the approximately three-mile Project corridor that will be aligned to traverse mostly under the Oneawa Hills range *mauka* of Kaneohe Bay Drive (multiple TMKs). The City and County of Honolulu Department of Environmental Services proposes to undertake improvements to the wastewater collection and treatment system in the Kāneʻohe-Kailua wastewater service area. The proposed Project involves the construction of a new conveyance system to supplement an existing force main carrying pre-treated wastewater from the Kāneʻohe WWPTF to the Kailua Regional WWTP.

8.1 Results of Background Research

Background research on the Project area and surrounding area of Kāneʻohe Ahupuaʻa indicates (presented in approximate chronological order):

1. The early settlers of the Hawaiian archipelago would have been attracted to the windward *moku* (district) of Koʻolaupoko on Oʻahu, especially the *ahupuaʻa* of Kāneʻohe, with its coral reefs, bays, and inlets for fishing, dense basalt dikes for the production of stone adzes and other tools, and amphitheatre-like basins and broad alluvial floodplains that contained fertile soils, permanently flowing streams, and high rainfall for the cultivation of crops (Kirch 1985:69). In Koʻolaupoko, the sand dunes of Bellows Beach (A.D. 300–400) in Waimānalo Ahupuaʻa (Kirch 1985:69–80) and Luluku (A.D. 500) in Kāneʻohe Ahupuaʻa (Allen 1987:265) are among the earliest Hawaiian archaeological sites. An archaeological site in close proximity to the Kāneʻohe WWRTF contains a vast assemblage of lithic artifacts radiocarbon dated to A.D. 1070–1405, which suggests that this area housed craftsmen specializing in the production of adzes and other stone tools (Clark and Riford 1986). Archaeological sites at Nuʻupia Fishpond adjacent to the Kailua WWTP similarly contain basalt tools, adze blanks, and flakes associated with stone tool manufacture (Hammatt et al. 1985; Jackson et al. 1993). Very few marine shellfish midden were recovered archaeologically, which suggests that Hawaiians once lived near the fishpond on a temporary or periodic basis (Jackson et al. 1993:78).

2. The settlers' descendants developed *loʻi kalo* (irrigated taro terraces) and other forms of agriculture, including the cultivation of *ʻuala* (sweet potatoes), *uhi* (yam), *maiʻa* (banana), *hala* (pandanus), *wauke* (paper mulberry), *ōlonā* (a native shrub used for cordage), and *ʻawa* (kava) (Handy and Handy 1972:456), and built at least 30 *loko iʻa* (fishponds) in the brackish waters of Kāneʻohe Bay for the harvesting of *ʻamaʻama* (mullet), *awa* (milkfish), and other fish (Devaney et al. 1982:114, 143–144; Summers 1964:2). Recent archaeological surveys near the Kāneʻohe WWRTF documented a taro terrace (Clark and Riford 1986) and subsurface agricultural soil indicative of taro production (Hammatt and Borthwick 1989).

3. Kāneʻohe Ahupuaʻa contains numerous *wahi pana* (storied places) and associated *moʻolelo* (stories, oral traditions) that place the specific Project area within a broader cultural context. One *moʻolelo* in particular illuminates the entire landscape of the

ahupuaʻa, from the mountain peaks (Keahiakahoe) and upland forests (Puʻu Kahuauli) to the coastal waters (Puʻu Pahu) and offshore islands (Moku o Loe) by chronicling a sibling rivalry (Hawaiian Ethnological Notes ms. Vol. 2:2181, cited in Sterling and Summers 1978:206; Landgraf 1994:94). Several *wahi pana* are located in the vicinity of the Kāneʻohe WWPTF and the Kailua WWTF, as well as on the *ʻili* of Waikalua, Keana, Mahinui, Kalāheo, Paʻalae, Pūʻahuʻula, Mālaʻe, and ʻAikahi (Lyons 1876; Wall 1914) above the subsurface Project corridor along the Kāneʻohe Bay shoreline. Waikalua Loko Fishpond, located immediately *makai* (seaward) of the Kāneʻohe WWPTF, measures over 1,400 feet in length and contains four *mākāhā* (sluice gates) (McAllister 1933:176). Laʻa, a navigator from Kahiki—the ancestral homeland of Hawaiians and other Polynesians—arrived nearby on the north side of the mouth of Kāneʻohe Stream, which was called Nāonealaʻa (sands of Laʻa) and is now Kāneʻohe Beach Park (Kamakau 1867; Thrum 1916:90). In the twelfth century, the *aliʻi* (chief) ʻOlopana erected the massive structure of Kāwaʻewaʻe Heiau, located about one mile east of the Kāneʻohe WWPTF, to sacrifice the pig demigod Kamapuaʻa (Kalākaua (1990:142–147; McAllister 1933:179; Thrum 1916:90). Nuʻupia Fishpond, located immediately north of the Kailua WWTF, and two adjacent fishponds (Halekou and Kaluapuhi) once separated Mōkapu from the main land of Kāneʻohe (McAllister 1933:184).

4. On the leeward half of Mōkapu Peninsula in Kāneʻohe Ahupuaʻa, excavations in the mid-twentieth century unearthed over 1000 *ilina* (burials) in the sand dunes (Kirch 1985:111). The Mōkapu dunes were most likely established burial grounds for the residents of several villages located on the windward half of the peninsula in Heʻeia Ahupuaʻa (Sterling and Summers 1978:217). A limestone cobble pavement close to the northern boundary of the Kailua WWTP may cover a burial (Jackson et al. 1993), but there is no documented evidence from archaeological surveys, historical records or oral traditions of *ilina* or *iwi kūpuna* (ancestral remains) within the Project area.
5. In the 1780s, Kahekili, the *mōʻī* (king) of Maui, met and defeated Kahahana, the *mōʻī* of Oʻahu, in the valley of Nuʻuanu, and after his victory he lived at Kailua while most of his *aliʻi* (chiefs) and followers stayed in Kāneʻohe and Heʻeia (Kamakau 1992:138). In 1795, Kamehameha similarly met Kalanikupule in Nuʻuanu Valley during his invasion of Oʻahu, and after his victory at the Battle of Nuʻuanu, he retained the *ahupuaʻa* of Kāneʻohe and Heʻeia as his own personal property (ʻĪʻī 1959:69–70).
6. The most impressive *ala hele* (trail) in the *ahupuaʻa* of Kāneʻohe formerly traversed the sheer cliff rocks of the Nuʻuanu Pali to the base of the mountains. Hawaiians used this steep path to transport taro, *poi* (pounded taro), potatoes, chickens, goats, and pigs between Honolulu to windward Oʻahu (Thrum 1901:89). Kamehameha III, in response to agricultural development in Kāneʻohe and other *ahupuaʻa* on windward Oʻahu, secured funds in 1845 to make the trail accessible to horses by paving the path with stones. In 1882, construction began to widen and reduce the grade of the road. The improved Pali Road opened in 1897 after workers found an estimated 800 skulls along with other bones at the bottom of the Pali—the remains of the warriors defeated by Kamehameha in 1795 (*Island Call* 1953). The road was maintained for 55 years until work began in 1952 to

construct a new four-lane highway with two tunnels running under the site of the Nuʻuanu battle (Devaney et al. 1982:172).

7. The middle nineteenth century marked the introduction of private and public land ownership laws to Hawaiian society during the Māhele (division of Hawaiian lands). No *kuleana* (Native Hawaiian land rights) claims were awarded near the Kailua WWPT, but testimonies associated with Land Commission Awards (LCAs) reveal that Hawaiians used the land near the Kāneʻohe WWPTF primarily to grow taro and *kula* (dryland) crops and had built *loko iʻa* along the coast of Kāneʻohe Bay (Waihona ʻAina 2000). The coastal flat area between Kāneʻohe and Kawa Streams immediately *mauka* of the Waikalua Loko Fishpond, known as the Waikalua Swamp and now the site of the Kāneʻohe WWPTF, was an area of intense production of taro. Claimants who resided in other *ʻili* with less reliable sources of fresh water tended to maintain *loʻi* in the Waikalua Swamp area as *lele* (a detached part or lot of land belonging to one *ʻili* and located in another) (Waihona ʻAina 2000).
8. Successive eras of commercial rice and sugar cultivation, ranching, pineapple farming, and dairy farming transformed the land of Kāneʻohe Ahupuaʻa. In particular, ranching in the mid-nineteenth century, which extended from the ocean to the *pali*, quickly caused environmental degradation and severely modified the landscape in the *mauka* regions (Devaney et al. 1982). Japanese and other immigrant families converted the *loʻi kalo* to rice paddies and sugar cane fields in the late nineteenth century, and pineapple field clearance in the early twentieth century likely destroyed many archaeological sites in the *mauka* regions (Kelly 1987).
9. Descendants of immigrant families, such as Joe Takebayashi (Fanning 2008:82–90) and Kenneth Fusao Wakabayashi (Fanning 2008:94–106), fished and hunted crabs throughout Kāneʻohe Bay in the early 1900s. Their testimonies also indicate how that the Japanese utilized the *mākāhā* of fishponds to store their catch and formed fishing “camps” along the waterfront.
10. Following World War II, residential developments in Heʻeia expanded. The U.S. military filled in six *loko iʻa* in Kāneʻohe Bay to provide land for residential lots (Dorrance 1998:95). The newly constructed Wilson Tunnel on the Likelike Highway and the expansion of the Pali Highway in the 1950s and 1960s allowed easier access from Honolulu through the Koʻolau Mountains to windward communities, and this led to increased residential developments. The Kāneʻohe sewage treatment plant was constructed in 1963, converted to a wastewater pump station in 1978, converted to a preliminary treatment facility in 1994, and upgraded in 1998. The Kailua WWTP was built in 1965 and expanded in 1994 (City and County of Honolulu 2009).

8.2 Results of Community Consultation

CSH attempted to contact 35 community members and government agency and community organization representatives. Of the 14 people that responded, four *kūpuna* (elders) and/or *kamaʻāina* (Native-born) participated in formal interviews for more in-depth contributions to the

CIA. CSH also presented the Project information to the Koʻolaupoko Hawaiian Civic Club and the OIBC. This community consultation indicates:

1. *Kamaʻāina* of Kāneʻohe Ahupuaʻa associate the vicinity of the Project area with several *wahi pana* and *moʻolelo*, which reveals a strong connection to past traditions and a renewed salience of those traditions today. For example, Ms. Cypher and Mr. Wolfgramm recall *moʻolelo* of Nāonealaʻa, the sands of the navigator Laʻamaikahiki (Laʻa). Mr. Wolfgramm adds that to provide a smooth landing place for his canoes, Laʻamaikahiki ordered his followers to mine the black cinder lava on Mōkapu and then transport the sands by canoe, a feat that required over 3000 crossings of Kāneʻohe Bay. Years later, according to Ms. Cypher, Nāonealaʻa was the site of a peace-making process. Mr. Wolfgramm also notes that Mālaʻe, a peninsula along the Kāneʻohe shoreline, provided a suitable landing area and tactics training for Nāonealaʻa marine and army units, and currently marks an anchorage for voyaging ships. According to Ms. Cypher, *moʻolelo* also describe that the gods created the first man out of the sands of Mōkapu.
2. A strong connection to ancestral land is based on lived experiences with *loʻi kalo*. Mrs. Hewett and Mrs. Kaluhiwa recall the intense productivity of the taro fields during their childhoods in the *mauka* lands of Haʻikū and the *makai* lands near Heʻeia Fishpond, respectively. Mrs. Hewett's family prepared taro in a variety of ways as their staple food, including steamed taro and taro hotcakes, and they sold *poi*. She recollects how the freshwater springs and rivers created a natural wetland region for taro production. Mrs. Kaluhiwa notes the remnants of two *poi* mills near Heʻeia Fishpond. Now, under the auspices of the Koʻolaupoko Hawaiian Civic Club, Mrs. Kaluhiwa and Mrs. Hewett are spearheading an initiative to restore the vast *loʻi kalo* of their childhood.
3. The Haʻikū lands of Heʻeia Ahupuaʻa and other *mauka* regions in Kāneʻohe Ahupuaʻa supported an abundance of papaya, banana, and bamboo, as well as medicinal plants. Mrs. Hewett and Mrs. Kaluhiwa recount how their families gathered plants for Hawaiian medicines, such as *ʻōlena* (turmeric) and *māmaki* (an endemic nettle) (See Appendix B for scientific and common names of plants and animals mentioned by community participants). Mrs. Kaluhiwa also describes a family burial cave high on the ʻIolekaʻa mountain cliffs in Heʻeia Ahupuaʻa that may have been accessed with *hau* (beach hibiscus) rope, and shares a poignant childhood memory of using flowers including *puakenikeni* (perfume flower), *pikake* (Arabian jasmine), and *pakalana* (Chinese violet) trees to fragrantly incense the family's outhouses.
4. The *kamaʻāina* of Kāneʻohe and Heʻeia Ahupuaʻa also had access to the marine and freshwater resources of Kāneʻohe Bay. Mrs. Kaluhiwa caught *āholehole* (young stage of the *āhole*, Hawaiian flagtail), *weke* (goatfish), *ʻamaʻama* (striped mullet), *awa* (milkfish), and *manini* (convict tang), gathered *ʻōpae lōlō* (brackish-water shrimp) and oysters, and hunted a variety of crabs, including *ʻaʻama* on the shore rocks and *haole* crabs and *kūhonu* farther offshore. Mrs. Hewett also fished and hunted for crabs and, with access to Heʻeia Fishpond, caught and consumed *ʻōʻio* (ladyfish, bonefish), while Mr. Takebayashi raised mullet in Waikalua Loko Fishpond and Mikiola Fishpond. Mrs. Hewett also recollects that the taro fields once maintained populations of *ʻōpae* (freshwater shrimp), which she used to collect with the spine of a coconut palm.

5. Japanese immigration and the eras of pineapple cultivation, rice cultivation, and the dairy industry have significantly added to the character of Kāne‘ohe. Mrs. Hewett recalls several Japanese dairy farming families who sold their produce at stands on the old Pali Road, and Mr. Takebayashi acknowledges his father and other Japanese who were the stewards of Waikalua Loko Fishpond.
6. Ms. Cayan, representing SHPD, is concerned that the proposed Project may uncover burials or other cultural resources that may have been covered by the construction of the Kāne‘ohe WWPTF and the Kailua Regional WWTP, and that the boring technology may penetrate into unknown cultural resources, including possible burials. More specifically, Ms. Cypher states that the construction of the proposed Project may impact the cultural sites and areas of Waikalua Loko Fishpond, Nāoneala‘a, the ridge separating the *ahupua‘a* of Kāne‘ohe and Kailua, and Mōkapu.
7. Ms. Cypher is concerned about allowing additional population growth in an area already heavily populated, and also seeks better protection for the natural and cultural resources of Kāne‘ohe Bay. She believes that if the proposed Project enables more people to live in the region beyond current trends in natural population growth, there would be cultural impacts on Native Hawaiians and descendants of the earliest immigrant families, including the possibility of an increase in crime, a decreased connection to natural resources, decreased access to fishing grounds and gathering places, pressure to develop more in Kāne‘ohe and along the northern coast of Ko‘olaupoko Moku, more competition for affordable housing, and the loss of land. In addition, Ms. Cypher is concerned that excavated material will overflow into the bay and adversely impact fishing, crabbing, and clamming areas.
8. Mr. Wolfgramm draws inspiration from the *‘ōlelo no‘eau* (proverb), “*Ka ulu koa ikai o Oneawa* (The *koa* grove at the seaside of Oneawa) and his current practices in Waiāhole Valley to suggest that the barren landscape of Oneawa Hills be restored to a sustainable native Hawaiian forest.

8.3 Impacts and Recommendations

Based on the information gathered for the cultural and historic background and community consultation detailed in this CIA report, CSH foresees potential impacts of the proposed Project on Native Hawaiian or other ethnic groups’ cultural practices customarily and traditionally exercised for subsistence, cultural or religious purposes, and on cultural, historic, and natural resources. CSH clarifies these potential impacts and makes the following recommendations:

1. Land-disturbing activities may uncover burials or other cultural resources that have been covered by the current wastewater systems, and the boring technology may penetrate into unknown cultural resources, including possible burials. The Kāne‘ohe WWPTF is located near the Waikalua Loko Fishpond and Nāoneala‘a, and the Kailua WWTF is located near Nu‘upia Fishpond and Mōkapu. Archaeological surveys in the vicinity of these two areas have uncovered evidence of stone tool production and habitation (Clark and Riford 1986; Hammatt et al. 1985; Jackson et al. 1993), as well as a possible burial near the Kailua WWTP (Jackson et al. 1993). Further, the Kailua WWTP is located adjacent to Jaucus

sand deposits, which often contain burials throughout the Hawaiian Islands. Should historic, cultural or burial sites or artifacts be identified during ground disturbance, the City and County of Honolulu, or its agent, should immediately cease all work and notify the appropriate agencies pursuant to applicable law.

2. Cultural practices, such as fishing, crabbing, and clamming, and recreational activities, such as paddling and sailing, occur along the coast and in the waters of Kāneʻohe Bay. If construction of the proposed Project (e.g. removal of excavated material from the proposed tunnel) results in adverse water quality (e.g., silt, sewage) of the rivers, fishponds, and bay waters near the Kāneʻohe WWPTF and the Kailua Regional WWTF, there may be impacts to these resources and activities. The City and County of Honolulu should implement best management practices to avoid or reduce impacts of the Project construction on the marine environment and nearby water-based cultural and recreational activities.
3. The boring of the proposed tunnel involves the extraction of a substantial amount of crushed basalt rock, which will need to be transported off-site. Although CSH is not aware of any cultural practices that currently take place along the major roads in the vicinity of the Kāneʻohe WWPTF or the Kailua Regional WWTF, the City and County of Honolulu and Wilson Okamoto Corporation should consult with community organizations and implement best management practices to avoid or reduce impacts of the removal of excavated material (e.g., high volume of dump trucks and associated increase in noise disturbance and blowing dust) on any cultural practices (e.g., prayers, gathering of medicinal plants).

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Appendix A Glossary

To highlight the various and complex meanings of Hawaiian words, the complete translations from Pukui and Elbert (1986) are used unless otherwise noted. In some cases, alternate translations may resonate stronger with Hawaiians today; these are placed prior to the Pukui and Elbert (1986) translations and marked with "(common)."

Diacritical markings used in the Hawaiian words are the *‘okina* and the *kahakō*. The *‘okina*, or glottal stop, is only found between two vowels or at the beginning of a word that starts with a vowel. A break in speech is created between the sounds of the two vowels. The pronunciation of the *‘okina* is similar to saying "oh-oh." The *‘okina* is written as a backwards apostrophe. The *kahakō* is only found above a vowel. It stresses or elongates a vowel sound from one beat to two beats. The *kahakō* is written as a line above a vowel.

Hawaiian Word	English Translation
ahupua‘a	Land division usually extending from the uplands to the sea, so called because the boundary was marked by a heap (*ahu*) of stones surmounted by an image of a pig (*pua‘a*), or because a pig or other tribute was laid on the altar as tax to the chief.
ala hele	Pathway, route, road, way to go, itinerary, trail, highway, means of transportation.
ali‘i	Chief, chiefess, officer, ruler, monarch, peer, headman, noble, aristocrat, king, queen, commander.
‘ama‘ama	Mullet (*Mugil cephalus*).
‘aumakua	Family of personal gods, deified ancestors who might assume the shape of sharks, owls, hawks (etc…). A symbiotic relationship existed; mortals did not harm or eat *‘aumakua*, and *‘aumakua* warned and reprimanded mortals in dreams, visions, and calls.
‘āpana	Piece, slice, portion, fragment, section, installment, part, land parcel, lot, district, sector, ward, precinct.
‘auwai	Ditch, canal.
‘awa	Kava (*Piper methysticum*).
awa	Milkfish (*Chanos chanos*).
hala	Pandanus or screw pine (*Pandanus odoratissimus*).
heiau	Pre-Christian place of worship, shrine; some *heiau* were elaborately constructed stone platforms, others simple earth terraces. Many are preserved today.

‘ili	Land section, next in importance to an ahupua‘a and usually a subdivision of an *ahupua‘a*.
ilina	Grave, tomb, sepulcher, cemetery, mausoleum, plot in a cemetery.
imu	Underground oven.
iwi kūpuna	Ancestral bone remains (common).
kahuna	Priest, sorcerer, magician, wizard, minister, expert in any profession.
kama‘āina	Native-born, one born in a place, host; native plant; acquainted, familiar, Lit., land child.
konohiki	Headman of an *ahupua‘a* land division under the chief.
kula	Plain, field, open country, pasture. An act of 1884 distinguished dry or kula land from wet or taro land.
kuleana	Native Hawaiian land rights (common). Right, privilege, concern, responsibility, title, business, property, estate, portion, jurisdiction, authority, liability, interest, claim, ownership, tenure, affair, province.
kupuna	Elders (common). Grandparent, ancestor, relative or close friend of the grandparent's generation, grandaunt, granduncle. *Kūpuna*—plural of *kupuna*.
lei niho palaoa	*Lei* of rock oyster shell.
lo‘i	Irrigated terrace, especially for taro, but also for rice; paddy.
loko i‘a	Fishpond (common).
Māhele	Division of Hawaiian lands.
maka‘āinana	Commoner, populace, people in general
mākāhā	Sluice gate, as of a fish pond.
makai	Seaward.
mai‘a	All kinds of bananas and plantains.
mana	Supernatural or divine power.
mauka	Inland.
moku	District, island, islet, section.
mō‘ī	King, sovereign, monarch, majesty, ruler, queen.
mo‘o	Lizard, water spirit; narrow strip of land
mo‘olelo	Story, tale, myth, history, tradition, literature, legend, journal, log, yarn, fable, essay, chronicle, record, article; minutes, as of a

	meeting. (From *moʻo ʻōlelo*, succession of talk; all stories were oral, not written).
nuku	Mountain pass.
ʻohe	All kinds of bamboo.
ʻōlelo noʻeau	Proverb, wise saying, traditional saying.
oli	Chant that was not danced to, especially with prolonged phrases chanted in one breath, often with a trill at the end of each phrase; to chant thus.
ōlonā	A native shrub (*Touchardia latifolia*).
pali	Cliff, precipice, steep hill or slope.
pōhaku	Rock, stone.
poi	*Poi*, the Hawaiian staff of life, made from cooked taro corms, or rarely breadfruit, pounded and thinned with water.
ʻuala	Sweet potato (*Ipomoea batatas*)
uhi	Yam (*Dioscorea alata*)
wahi pana	Storied place (common). Legendary place.
wauke	Paper mulberry (*Broussonetia papyrifera*).

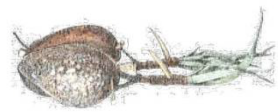
Appendix B Common and Scientific Names for Plants and Animals Mentioned by Community Participants

Common Names		Possible Scientific Names		Source
Hawaiian	Other	Genus	Species	
‘a‘ama	crab	*Grapsus*	*grapsus tenuicrustatus*	Pukui and Elbert 1986
āholehole	juvenile *āhole* (Hawaiian flagtail)	*Kuhlia*	*xenura*	Hoover 1993
‘ama‘ama	striped mullet	*Mugil*	*cephalus*	Hoover 1993
awa	milkfish	*Chanos*	*chanos*	Hoover 1993
haole (*kūhonu*)	white crab	*Portunus*	*sanguinolentus*	Pukui and Elbert 1986
hau	beach hibiscus	*Hibiscus*	*tiliaceus*	Wagner et al. 1999
kalo	taro	*Colocasia*	*esculenta*	Wagner et al. 1999
kūhonu	crab	*Portunus*	*sanguinolentus*	Pukui and Elbert 1986
māmaki	an endemic nettle	*Pipturus*	spp. *	Wagner et al. 1999
manini	convict tang	*Acanthurus*	*triostegus*	Hoover 1993
‘ō‘io	bonefish	*Albula*	spp.	Hoover 1993
‘ōlena	tumeric	*Curcuma*	*domestica*	Pukui and Elbert 1986
‘ōpae lōlō	brackish-water shrimp or prawn	*Penaeus*	*marginatus*	Pukui and Elbert 1986
pakalana	Chinese violet	*Telosma*	*cordata*	Pukui and Elbert 1986
pīkake	Arabian jasmine	*Jasminum*	*sambac*	Pukui and Elbert 1986

Common Names		Possible Scientific Names		Source
Hawaiian	**Other**	**Genus**	**Species**	
puakenikeni	perfume flower	*Fagraea*	*berteriana*	Pukui and Elbert 1986
weke	surmullets or goatfish	Family Mullidae	spp.	Hoover 1993

Appendix C Authorization and Release Form

Cultural Surveys Hawaiʻi, Inc.
Archaeological and Cultural Impact Studies
Hallett H. Hammatt, Ph.D., President



P.O. Box 1114 Kailua, Hawaiʻi 96734 Ph: (808) 262-9972 Fax: (808) 262-4950
Job code: KANEOHE 15 jgenz@culturalsurveys.com www.culturalsurveys.com

AUTHORIZATION AND RELEASE FORM

Cultural Surveys Hawaiʻi appreciates the generosity of the *kūpuna* and *kamaʻāina* who are sharing their knowledge of cultural and historic properties, and experiences of past and present cultural practices for the Cultural Impact Assessment for the *ahupuaʻa* of Kāneʻohe.

We understand our responsibility in respecting the wishes and concerns of the interviewees participating in our study. Here are the procedures we promise to follow:

1. The interview will not be tape-recorded without your knowledge and explicit permission.
2. If recorded, you will have the opportunity to review the written transcript of our interview with you. At that time you may make any additions, deletions or corrections you wish.
3. If recorded, you will be given a copy of the interview notes for your records.
4. You will be given a copy of this release form for your records.
5. You will be given any photographs taken of you during the interview.

For your protection, we need your written confirmation that:

1. You consent to the use of the complete transcript and/or interview quotes for reports on cultural sites and practices, historic documentation, and/or academic purposes.
2. You agree that the interview shall be made available to the public.
3. If a photograph is taken during the interview, you consent to the photograph being included in any report/s or publication/s generated by this cultural study.

I, ________________________________, agree to the procedures outlined above and, by my
(Please print your name here)
signature, give my consent and release for this interview to be used as specified.

____
(Signature)

____
(Date)

Appendix D Expanded Moʻolelo

1. *Moʻolelo* of Kāneʻohe: "Kaneʻohe, the Bamboo Man" (Paki 1972:29–30)

In olden times anyone who did not conform to the way of life lived so industriously by the shore people, was called E-epa, or non-conformist. The Eʻepa were not actually "touched in the head", or lo-lo [crazy], but just different. They liked to wander off by themselves and dwell among the mysteries of the upland forests where they listened to the music of Nature, and often became poets or musicians.

Those upland reaches, all unexplored territory and sacred to the Spirits or Akua of Nature, were referred to as the Wao [inland forest], or places of mystery. In order to keep children from wandering to the uplands, their elders told the little ones, "Do not go up there or the Bamboo Man may keep you. We would mourn your absence in loneliness. Remain at home and learn your useful duties."

Hano-ihu…longed to explore. Puʻili…longed to accompany her playmate, Hano-ihu, when he wandered far. But, being more timid, she contented herself during the boy's absences and kept his secret of those upland trips he enjoyed.

One sad day, Hano-ihu did not return. The people searched and could find no trace of the disobedient boy. Finally, the villagers decided the boy had died, and they told the other children that the Bamboo Man had taken the boy-wanderer.

Puʻili, very lonely indeed without her playmate, decided that he was not dead and she must search for him. Acting upon the thought, the little girl followed the direction often taken by the boy and was soon alone in the dark recesses of the forest lands of Wao, the Mysterious.

She saw nothing to fear. Rather, she delighted in the beauty of the forests, the fragrance of the ferns and blossoms growing besides singing rills of sweet waters, and danced along happily to the whistling of the Wind Gods in the tree tops touching the blue sky far above.

Soon she realized the whistling was not actually the Wind, for it had a bird-like note that repeated itself in a gentle rhythm. Also, she saw the bamboo moving in the breeze and heard how it rattled its branches. She found two lengths of a bamboo branch and, one in each hand, beat time on the two sticks while she followed the plaintive note calls.

Before her, where a grassy clearing formed a dell by a pool into which a lacy waterfall descended from a height above, she saw her beloved playmate sitting on the bank. Beside him was a tall, thin man whose eyes watched the boy, while the child blew upon a bamboo length. The man's lean hands waved to the rhythm of the notes, and the girl went dancing toward the pair, keeping time with her pair of bamboo sticks.

Hano-ihu and the tall man finished their melody, then praised the little Puʻili for joining them in creating pleasant melody.

She sat with them and learned that the man was Kaneʻohe, the Bamboo Man who, as a child, had followed the lure of Wao and had invented a bamboo flute. Kindly, the old man explained to the children how the art of creativity often is lost unless those inspired do follow the call. He told them, “Now we shall return to the village, for I have answered the call and you two little ones will be musicians like me. In honor of this occasion, I shall name the flute after you, my boy...we shall name the time-keeping sticks for her.”

Gaily, the three went down the forest trail of Wao the Inspiring. They were welcomed with feasting and joy. That is how we have the...Bamboo, instruments today. The Hano-ihu or Nose flute; and the Puʻili, or notched Bamboo sticks; and the hula named for these gifts of Kaneʻohe, the Bamboo Man.

2. *Moʻolelo* of Keahiakahoe: “Ke-ahi-a-Kahoe” (Hawaiian Ethnological Notes I:3179–3185, Bishop Museum Archives)

That is the tallest peak on the mountain above Ke-aʻa-ahala (The hala root) at Kaneʻohe.

There were brother and a sister from Moku-ʻume ʻume (Ford Island) and Kahua-iki at ʻEwa who were expelled for constantly fighting with their parents. The four who were sent away were Kahoe of Ke-ahi-a-Kahoe (male), Kahua-nui (male) who was also known as Kahua-uli, who home was at Luluku, Pahu or Puʻupahu (male) and Loʻe (female) whose name is found in Moku-o-Loʻe to this day.

The name Ke-ahi-a-Kahoe was derived from a deed committed by Pahu against Kahoe and Loʻe. which is given in the following account.

Kahoe was a farmer who lived on the Haʻiku side of Ke-aʻa-hala and so was Kahua-uli at Ka-ʻakau-wai at Luluku. Pahu was a fisherman, living on the He’eia side of that hill now know today as Puʻu Pahu (Pahu Hill). Their sister lived at the place that is still known as Moku-o-Loʻe (Loʻe’s Island).

All went well in the first days of their settling in that locality but there was an indifference and stinginess in Pahu that was not recognized by the other brothers and their sister. In those days Pahu went up to visit Kahua-uli and Kahoe always returned laden with loads of poi from them. With the sister, the brothers always brought her share to her.

After a passage of time the men took wives to themselves and an unhappy condition began. Pahu or Puʻu-pahu mated with Paʻu, a maiden across the valley and stream where he farmed. This place is on the upper side of a row of hills that separates Ke-aʻa-hala and Ka-puka-ʻuki.

One day Puʻu-pahu came down from the upland home of Paʻu his wife, accompanied by his brother-in-law, to fish in the early morning. Upon returning in the evening, Puʻu-pahu sent the latter to go home by the seaward side of the row of hills or ridge separating Ke-a’a-hala and Ka-puka-ʻuki. He went on alone before it to the upland where Kahoe was farming. As they met, Puʻu-pahu said, “You are in need, brother Kahoe, for all I have returned with is some bait.”

The meaning of these words was that he had some left over fish used as bait and the remainder were tiny ones. This was the beginning of deceit, as told in this tale, for the brother-in-law who went on another path had the ulua [crevalle, jack or pompano] and the kahala [amberjack or yellowtail] fish. This practice went on for a long time.

In all of this time Kahoe had no suspicion whatever until Loʻe arrived to get some vegetable food. It was after the evening that Puʻu-pahu had gone home with some kahala and other large fish.

When she met her brother (Kahoe), her first question to him "Have you removed the cooked ulua fish from the imu? Pahu returned with the brother-in-law of you two laden with kahala last evening. I received some amomomi."

The brother stared at her and replied, "He has been returning with the bait fish every evening!" After saying this he recalled something some fellow farmers had told him. Loʻe exclaimed at once, "Oh! Whenever he returned from the deep sea, there was never a time he had come without fish. How heartless of him!", and with this her tears fell. It was said that where Lo'e's tears fell, they formed a spring in front of the cliff of Ke-ahi-a-Kahoe facing Pauʻu and there it is to this day.

(Note, I do not remember this spring, for I did not hear this tale while I was in Kaneʻohe; I had gone there from ʻEwa to seek the things told me by A. Dickey. The spring was named Loʻe-wai.)

After Kahoe had heard this and saw the falling of her tears, he changed his residence and his farming place to the Haʻiku or Heʻeia side of the cliff standing there. He stopped doing anything for Puʻu-pahu except when he came in person to the door of his house. Only then did the latter receive anything. It was not like before, when Kahoe brought food to him.

A few weeks after Kahoe had changed his place of residence, Pahu and his wife went down to Ka-ʻopu-lolia to make their permanent residence. He continued in his trade of fishing. His brother-in-law always came down and the two went fishing together.

When Puʻu-pahu went to Ka-ʻopu-lolia to live, his brother-in-law supplied him with vegetable food. He, too, was a farmer and rarely was it ever heard that his home and family ever lacked food. But since his family was added to by his sister Paʻu and her children, Mr. Hunger and Mrs. Famine spread throughout Heʻeia and Kaneʻohe. Kahua-uli, Kahoe and a few others not mentioned in the story were exceptional cases. So let us turn back our narration to Ke-ahi-a-Kahoe and Puʻu-pahu the two "dwellers of Kahua-loa."

In the meantime Kahoe did not leave off farming at Ke-aʻa-hala, where he grew sweet potatoes, pumpkins and other food plants suitable for a plain like this one. The food plants requiring much water were planted on the other side of Haʻiku, all the way to the lowland of Hoi. This was a place in the center of Heʻeia Valley, that led to the fishpond of Heʻeia-uli. (I do not know or heard of this name while I was at Koʻolau).

When Puʻu-pahu returned again to dwell at Ka-ʻopu-lolia, he continued his daily fishing, but in those days life depended on the brother-in-law and on Kahua-uli. Kahoe did not actually refuse to give Puʻu-pahu any food, but the latter knew and heard that he had learned of his unkind deeds in the past.

It was several months after he and Paʻu had moved to the lowland that hunger and famine began to rage over the land. He went up to Kahua-uli to get some food and on the way he met with Kahoe. They had not seen each other in many months and were delighted at the meeting. As they were talking of the conditions of those days, Puʻu-pahu mentioned the trouble that they were in. He magnified the trouble and mentioned something that recalled a thought to Kahoe's mind, "I just took some bait fish to the others (Kahua-uli and his brother-in-law) on that side." He meant the other side of the valley that separated Paʻu and Ke-aʻa-hala. This raised the heat of anger in Kahoe, who replied, "How true that is. The famine in these days is indeed great. The bit of life-giving food is hard indeed to obtain. Therefore you are not receiving anything for all I have to sustain life are some broken pieces of sweet potatoes."

After a short conversation which followed this, Puʻu-pahu went on his way to his brother-in-law's. He failed to obtain any food at all from there and so he continued on to the presence of Kahua-uli on the other side of Luluku.

When he reached Kahua-uli's place, he came at a time when the latter and his family were peeling taro and so Pahu was asked to join them in the work so as to have it done while it was day. As the peeling ended, ti was late in the evening. Paʻu and the children were down at Ka-ʻopu-lolia waiting with hunger as darkness fell.

Pahu had never tried to pound poi in his life and this remaining in the upland until dark distressed his mind. Because of the love and kindness of Kakua-uli, he commanded some men who lived under him to fill Pahu's container with the first batch of poi made.

When Pahu received enough poi to last them a week or ten days it was already dark. (Perhaps it was the equivalent of eight or nine o-clock to us today). After receiving it, he hastened home, thinking of his family's hunger. It was quite late when he arrived at home, about 11 or 12 o'clock at midnight.

Upon reaching home, he found his family asleep. This caused anger and quarrelling between the two (his wife and himself).

Let us go on talking about the source of the name. Ke-ahi-a-Kahoe, on the cliff of Ke-aʻa-hala. It remains to this day in which the modern generation of this people live, the majority of the Hawaiian youths, who regard the seeking of the old lore a stupid and time wasting occupation.

Remember that in those days when the famine was at its worst, the cooking of food was kept secret, because when it was noticed, the place would be full of hungry people who looked with longing before the imu was opened. Therefore the others made it a habit to hid the imu full of food; to postpone the time of cooking until evening or at night, between nine o'clock and daybreak. When day came, the food was prepared and in the bowls and containers. In the daylight hours was the time going to and fro seeking things to benefit the family. Remember. It was the smoke of the imu who told the public, "So-and-so is baking food," and the time for the opening was then eagerly watched for. As soon as the imu was opened, women and children gathered about and it was said that some men did likewise. This one scooped that one grabbed, and before long the owner of the imu had nothing at all. That was why the cooking was done at night, but later the result was just the same.

As to this Kahoe, whom we are discussing, he did not preparing or cooking at night, for rarely was the smoke of his imu seen. Besides that, he and his family were quick in peeling and pounding the taro as they cooked.

The poi was mixed before the people gathered to scoop up the food and this deprived them. By the time the cheeky beggars arrived, they were sitting quietly, with all the food mixed and in large containers inside the house.

The reason that Kahoe was never caught cooking was his ability to conceal the smoke of the imu he lighted. While the imu was lighted, all those who watched eagerly for it never saw it. He had two dwellings, one was in a valley on the Haʻiku side of the cliff gearing his name and the other in another valley in front of Ke-aʻa-hala, on the side looking out toward the sea of Kaneʻohe. The other homes in which Kahoe lived in these valleys were far away from the spot where the smoke rose on the cliff which bore his name. When the fire was lighted in the imu, the smoke traveled a half or a whole mile before appeared at the summit of the cliff of Kahoe. Therefore whenever the imu was lighted, rarely did any man or woman recognize the time that Kahoe did it.

Remember now, when the imu made by Kahoe was being readied for the food, the smoke was not seen rising from that spot at all or anywhere near it. It crept along inside of the valley to the spot mentioned, a distant place of over a half a mile from where the fire was burning. This helped him greatly in keeping secret the time for the lighting of his imu for the fool of his family before beggars, the result of the bitter famine, arrived there.

Remember, these two homes of Kahoe, standing at Haʻiku and Ke-aʻa-hala, were alike in being so well situated. The smoke appeared at the same spot and rose at the edge of the cliff.

Now let us turn over the conversation to Pahu and his family down at Ka-ʻopu-lolia.

About three or four months after they had moved to Ka-ʻopu-lolia, where they found the worst of hunger because of the lack of food, the planting fields of his brother-in-law failed to grow dry land food, such as sweet potatoes, and wet land food such as taro, therefore the welfare of three families depended on one person to feed them and that was Kahua-uli at Luluku, a distance of about a mile from Paʻu, where Pahu's brother-in-law lived with his family.

One of the warmest days of the warmest month, Makalii, Loʻe thought of Ka-imi-hana, a lover of hers. He was the favorite brother of ʻUla-i-ka-poki and the two lived on the eastern side of the place where Pahu dwelt with his wife and children.

Remember, O Reader, this was the day on which Loʻe mentioned something about Kahoe's cliff. It (the smoke) was discovered as he (Pahu) stood by the wall of their shed and gazed up at Ke-aʻa-hala. His arms were crossed behind him (in sorrow) that day because of his lack of food and hunger. He recalled the things he did to Kahoe, who in turn, did not disown him. He had come out doors that evening with hands crossed behind his back and turned his face to look at Ke-aʻa-hala where his oldest brother was living.

As he looked toward the upland, without turning behind him to the sea, Loʻe arrived. Because of Loʻe's affection for her oldest brother and remembrance of what she had heard of the unkindness of this brother to him, she said to him sternly, "So! Standing at the wall of the house with eyes gazing at Ke-ahi-a-Kahoe (Kahoe's fire)." Pahu was startled by the voice behind him, and when he turned about he saw his sister with an amused look on her face. He offered no reply for she had already given him a verbal lambasting in the past for his treatment of Kahoe.

Therefore at seeing his sister, he looked up once more and returned indoors. After he had gone in, she continued on her way to Ka-ʻimi-hana, her heart's desire.

I recall the name Ka-ʻimi-hana, as the name of a spring on the west corner of the large taro patch lying close to and above ʻula-i-ka-poki. The name was also applied to the large taro patch during the lifetime of Alapaʻi and Kikaha, my beloved parents who have gone to the other side of the round world, where all must go. There also will I follow them.

3. *Moʻolelo* of Kamapuaʻa and Kāwaʻewaʻe Heiau (Kalākaua 1990:142–147)

Glancing back a half-century or more before the landing of the Pele family in Puna, we note the arrival in the group of a number of independent parties of immigrants or adventurers from the southern islands. Among them were the chiefs Kalana and Huma. They came with considerable of a following, including the beautiful Kamaunui and a few of her relatives. The party landed on the island of Maui, and, after some wandering and change of locations, finally settled in Waihee, a spot noted for its beauty and natural advantages. Huma loved the fair Kamaunui. He had whispered soft words to her on their long journey form Kahiki, and fed her with the choicest food to be found among the stores of his great double canoe; but she loved Kalana better, and, when she became his wife, Huma abruptly left Waihee, returning, it is supposed, to his native land.

The only child of this marriage was Hina, who on reaching womanhood became the wife of Olopana, a chief of the island of Oahu. Although of the same name, he was in nowise related to the Olopana who was the brother of Moikeha and grandson of Maweke. This chief had arrived from the south a few years before his marriage with Hina, and, with his younger brother, Kahikiula, settled in Koolau, or on the Koolau side of the island of Oahu, where he had acquired very considerable possessions. By what chance he met Hina, or through what influence he won her, tradition does not mention, but as his wife she went with him to Oahu, and there remained.

Hina was fair, and Kahikiula, unlike his brother, was young and handsome. They were happy in society of each other, and were therefore much together. She went with him to the hills for wild fruits and berries, and he followed her to the seashore to gather shells and limpets. The jealousy of Olopana was at last aroused, and when Hina presented him with a son he charged Kahikiula with its paternity and refused to accept the child as his own. This estranged the brothers and made the lot of Hina miserable.

From its birth Olopana disliked the child, and in his resentment named it Kamapuaa, signifying a hog-child, or child of a hog. As the infant showed no marked physical characteristics of that animal, it is probable that Olopana fastened upon I the graceless appellation in a spirit of retaliation. But, whatever may have prompted its bestowal, the child certainly bore the name through life, thus giving to the bards who chanted the story of his acts the cue and pretext for shaping him into the monster depicted by tradition.

Having no love for Kamapuaa, Olopana took little interest in his growth from year to year to the mighty manhood which he finally attained, and which excited the admiration of all others. The more Kamapuaa was praised the greater dislike did Olopana feel for him, and at length the presence of the young giant became so obnoxious to him that he ordered him, under penalty of death, to leave the district.

Failing to understand the cause of this unnatural hatred, the anger of Kamapuaa was at last aroused, and he strode away from the home of his youth with his heart filled with bitterness and vows of vengeance. As he left, Kahikiula presented him with a long and finely-finished spear tipped with bone, and his mother threw over his broad shoulders the feather cape of a chief, and hung around his neck a *palaoa* [sperm whale], or talisman carved from the tooth of some great animal of the sea.

Kamapuaa knew of a large cavern in the hills some miles distant from Koolau, the name by which will be designated the place of his birth, and thither he repaired and took up his residence. He led a wild, predatory life, and was soon joined by others as reckless as himself, until the party numbered fifty or sixty in all. Made bolder by this following, Kamapuaa began to harass the estates of Olopana. He stole his pigs, fowls and fruits, and whatever else his little band required, and delighted in breaking his nets, cutting adrift his canoes and robbing his fish-ponds. In a spirit of youthful bravado he had his body, from his loins upward, tattooed in black, shaved his head and beard to the resemblance of bristles, and hung from his shoulders a short mantle of tanned hog-skin, the hair being left to be worn on the outer side. In his guise his name did not seem to be altogether inappropriate, and he was pleased at the terror his appearance inspired.

Becoming still bolder, Kamapuaa resolved to inaugurate a more vigorous warfare upon Olopana, and began to cut down his cocoanut-trees and destroy his growing crops. This brought the matter to a crisis, as such acts were always regarded as a declaration of war. The depredations of Kamapuaa were invariably committed at night, and it was some time before the real aggressors were discovered. Koolau was filled with stories of the marauding exploits of a lawless band, led by a monster half-man and half-hog, and the *kahunas* were called upon to ascertain the character of the spoilers, and, if found to be supernatural, placate them with sacrifices.

While the *kilos* [astrologers] were plying their arts the mystery was suddenly solved in a more practical manner. Detected one night in destroying the walls of one of Olopana's fish-ponds, Kamapuaa and a number of his party were secretly followed to their hiding-place in the hills. This information was brought to Olopana, and he promptly equipped a small force of warriors to follow and capture or destroy the plundering band, which, he was enraged beyond all measure in learning, was under the leadership of his outcast son or nephew, Kamapuaa.

But the task of capturing or destroying Kamapuaa and was band was by no means an easy one. Of the party first sent to attack them in their mountain stronghold all were killed with the exception of a single warrior, and he was allowed to return to tell the tale of the slaughter and take to Olopana the defiance of Kamapuaa.

This satisfied the chief that Kamapuaa's purpose was rebellion as well as pillage, and a force of six hundred warriors was organized and sent against the outlaws. This forced Kamapuaa to change his tactics, and, leaving their retreat, in which they might have been surrounded and brought to submission by famine, the rebels retired farther back into the mountains, where they for months defied the whole force of Olopana. Frequent skirmishes occurred and many lives were lost, but every attempt to surround and capture the desperate band was frustrated by the dash and sagacity of their leader.

Once, when closely pursued and pressed against the verge of a narrow gorge, the rebels crossed the chasm and escaped to the other side by some means unknown to their pursuers, and the story was told and believed that Kamapuaa, taking the form of a gigantic hog, had spanned the gorge and given his followers speedy passage over his back to the other side, when he leaped across at a single bound and escaped with them. The spot marking this marvelous achievement is still pointed out at Hauula, and the tracks of the monster in the solid rock are shown.

It is difficult to say just how long this desultory fighting continued, but in the end the rebels were surrounded and nearly destroyed, and Kamapuaa was captured unhurt and delivered over to Olopana, to the great joy and relief of the people of Koolau. Olopana had erected a *heiau* at Kaneohe, where Lonoaohi officiated as high priest, and thither he resolved to take his rebellious son or nephew, and offer him as a sacrifice to the gods. Hina pleaded for the life of Kamapuaa, but Olopana could not be moved. Satisfied that he would listen to no appeals for mercy, she determined to save her son, even at the sacrifice of her husband, and to that end secured the assistance of the high-priest, through whose treachery to Olopana the life of Kamapuaa was saved.

On the day fixed for the sacrifice Kamapuaa, carefully bound and strongly guarded, was taken to the *heiau*, followed by Olopana, who was anxious to witness the ghastly ceremonies, and with his own eyes see that his troublesome enemy was duly slain and his body laid upon the altar. In offering human sacrifices the victim was taken without the walls of the *heiau* and slain with clubs by the assistants of the high-priest. The body was then brought in and placed upon the altar in front of the entrance to the inner court, or sanctuary, when the left eye was removed by the officiating priest, and handed, if he was present, to the chief who had ordered the sacrifice. This being done, the offering was then ceremoniously made, and the body was left upon the alter for the elements to deal with.

Standing with three or four attendants, at the door of his retreat, within forty of fifty paces of the altar, Olopana saw his victim preliminarily led to the place of sacrifice, and a few minutes after motioned for the ceremonies to begin. Kamapuaa was taken without the walls of the temple to be slain. He was in charge of three assistant priests, one of them leading him by a stout cord around his neck, another keeping closely behind him, and the third walking silently at his side with the club of execution in his hand. Passing beyond the outer wall, the party entered a small walled enclosure adjoining, and the executioner raised his club and brought it down upon the head of his victim. Kamapuaa smiled, but did not move. Twice, thrice with mighty sweep the club descended upon the head of Kamapuaa, but scarcely bent the bristly hairs upon his Crown.

With a semblance of wonder the executioner, whose tender blows would have scarcely maimed a mouse, dropped his club and said:

"Three times have I tried and failed to slay him! The gods refuse the sacrifice!"

"It is so, it is so, it is so!" chimed his companions. "The gods indeed refuse the sacrifice! We have seen it!"

Therefore, instead of slaying Kamapuaa, the assistants, as they had been secretly instructed to do by the high-priest, removed the cords from his limbs, smeared his hair, face and body with the fresh blood of a fowl, and on their shoulders bore him back and placed him upon the altar as if dead.

The high-priest approached the apparently lifeless body, and bent for a moment over the face, as if to remove the left eye; then placing on a wooden tray the eye of a large hog, which had been procured for that purpose, he sent an assistant with it to Olopana, at the same time retiring within the inner court, and leaving by the side of Kamapuaa, and near his right hand, as if by accident, the sharp ivory *pahoa*, or dagger, with which he had, to all appearance, been operating.

Giving but a single glance at the eye presented to him by the assistant of the high-priest, Olopana passed it to an attendant without the customary semblance of eating it, and approached the altar alone. Kamapuaa did not breathe. His face was streaked with blood, his eyelids were closed, and not a single muscle moved to indicate life.

Olopana looked at the hated face for a moment, and then turned to leave the *heiau*, not caring to witness the ceremonies of the formal offering. As he did so Kamapuaa clutched the dagger besides his hand, and, springing from the altar, drove the blade into the back of Olopana. Again and again he applied the weapon until the chief, with a groan of anguish, fell dead at the feet of his slayer.

Horrified at what they beheld, the attendants of Olopana sparing toward their fallen chief. But their movements, whatever their import, did not disturb Kamapuaa. He had been accustomed to meeting and accepting odds in battle, and when he had secured possession of the *ihe* [spear] and huge axe of stone conveniently placed for his use behind the altar, he boldy approached and invited an encounter.

But the challenge was not accepted. The attendants of the chief did not ordinarily lack courage, but they were unnerved at the sight of a victim, slain, mutilated and laid upon the altar by the priest, coming to life and springing to his feet full-armed before his enemies.

Appearing upon the scene, the high-priest expressed great surprise and horror at what had occurred, and his assistants wildly clamored at the sacrilege; but no hand was laid upon Kamapuaa, and the friends of Olopana finally left the *heiau*, taking his body with them.

This tragedy in the *heiau* of Kawaewae created a profound excitement in the district. Had Kamapuaa been at all popular with the masses the death of Olopana at his hands would have occasioned but little indignation; but as many beside the dead chief had suffered through his plundering visitations, and hundreds of lives had been sacrificed in his pursuit and final capture, the people rose almost in a body to hunt him down and destroy him.

Hina attempted to save her son from the wrath of his enemies, but her influence was insufficient to protect him, and he again sought refuge in the mountains; but his following was small, and he finally crossed the island, and, with a party of forty or fifty reckless and adventurous spirits, set sail for the windward islands in a fleet of eight or ten canoes which he in some manner obtained from the people of Ewa.

Appendix E Community Consultation Letter

Cultural Surveys Hawai‘i, Inc.
Archaeological and Cultural Impact Studies
Hallett H. Hammatt, Ph.D., President

P.O. Box 1114 Kailua, Hawai‘i 96734 Ph: (808) 262-9972 Fax: (808) 262-4950

Job code: KANEOHE 15 jgenz@culturalsurveys.com www.culturalsurveys.com

July 1, 2010

Aloha e Kāua,

At the request of Wilson Okamoto Corporation, Cultural Surveys Hawai‘i (CSH) is conducting a Cultural Impact Assessment (CIA) for the Proposed Kāne‘ohe-Kailua Wastewater Conveyance and Treatment Facilities Project, Alternative 2–Tunnel Route, Kāne‘ohe Ahupua‘a, Ko‘olaupoko District, O‘ahu Island (Multiple TMKs). The approximately three-mile long Project will be aligned to traverse mostly under the Oneawa Hills range *mauka* of Kaneohe Bay Drive.

The City and County of Honolulu Department of Environmental Services (ENV) proposes to undertake improvements to the wastewater collection and treatment system in the Kāne‘ohe-Kailua wastewater service area. The proposed project involves the construction of a new conveyance system to supplement an existing force main carrying pre-treated wastewater from the Kāne‘ohe Wastewater Pre-Treatment Facility (WWPTF) to the Kailua Regional Wastewater Treatment Plant (WWTP). An alternative solution involves the construction of a force main.

The proposed Alternative 2–Tunnel Route involves construction of an approximately 13-foot diameter tunnel between the two facilities. The floor of the tunnel would begin at a depth of approximately 35 feet below sea level at the Kāne‘ohe WWPTF. It would traverse approximately three miles, mostly beneath the Oneawa Hills range, reaching a floor depth of approximately 62 feet below sea level at the Kailua Regional WWTP, where the wastewater will be pumped to the surface for treatment by a new influent pump station (IPS). In addition to conveying wastewater by gravity flow, the tunnel would also serve a storage function when the volume of wastewater increases during periods of high rainfall. The tunnel alternative would allow the existing Kāne‘ohe WWPTF and existing force main to be taken out of service.

The proposed sewer tunnel would be constructed by tunnel boring machinery and could be staged from either the Kāne‘ohe WWPTF or the Kailua Regional WWTP. An intermediate tunnel access shaft would also be constructed near the midpoint of the tunnel. Near-surface land disturbance associated with the proposed project would occur in the vicinity of the Kāne‘ohe WWPTF, the intermediate access shaft, and the Kailua Regional WWTP. Horizontal boring associated with the construction of the sewer tunnel would occur at depths greater than 45 feet and would likely have no effect on the near-surface sediments above. Spoils comprised mostly of un-weathered basalt generated by the boring will be extracted through the completed portion of the tunnel. The basalt will be removed as crushed rock, which can be readily processed for use as construction material.

The purpose of this CIA is to evaluate potential impacts to cultural practices and resources as a result of the proposed development in Kāne'ohe Ahupua'a. We are seeking your *kōkua* and guidance regarding the following aspects of our study:

- **General history and present and past land use of the Project area.**
- **Knowledge of cultural sites which may be impacted by future development of the Project area - for example, historic sites, archaeological sites, and burials.**
- **Knowledge of traditional gathering practices in the Project area both past and ongoing.**
- **Cultural associations of the Project area, such as legends and traditional uses.**
- **Referrals to descendents with lineal or cultural ties to Kāne'ohe Ahupua'a, *kūpuna*, and *kama'āina* who might be willing to share their cultural knowledge of the Project area and the surrounding *ahupua'a* lands.**
- **Any other cultural concerns the community might have related to Hawaiian cultural practices within or in the vicinity of the Project area.**

I invite you to contact me, Joe Genz, at 262-9972 or send me an email at jgenz@culturalsurveys.com if you have any information you would like to share.

Mahalo nui,

Joe Genz

Appendix I

Kaneohe–To–Kailua Wastewater Conveyance Project: Economic And Fiscal Impacts

Plasch Econ Pacific LLC

December 2010

Kaneohe-to-Kailua Wastewater Conveyance Project: Economic and Fiscal Impacts

by

Plasch Econ Pacific LLC

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1. Introduction

a. Content and Purpose

This report addresses the economic and fiscal impacts of the Kaneohe-to-Kailua Wastewater Conveyance Project ("the Project"). Its purpose is to provide government officials with information relevant to their decisions about the Project.

The analysis covers two conveyance alternatives: (1) a Force Main via a route under Kaneohe Bay, and (2) a Gravity Tunnel via a route under Oneawa Hills. The economic impacts cover expenditures and sales, employment, and payroll related to (1) construction and related activities, and (2) operations and related activities. Fiscal impacts address the impact of the Project on revenues of the State of Hawai'i (State) and of the City & County of Honolulu (City).

b. Methodology

Construction and Operating Costs

For the two alternatives, estimates of construction and operating costs were provided by Wilson Okamoto Corporation (WO) based on information provided by Project subconsultants and the City.

Multipliers

The construction and operating costs are translated into economic and fiscal impacts based on a number of multipliers (e.g, indirect sales generated per $1 million in direct construction and operating expenditures, payroll as a percentage of construction and operating costs, indirect jobs per direct job, average salary per job, tax rates, etc.). These multipliers reflect the professional judgment of the consultant, and are based on information from the following sources: WO and its subconsultants on the Project, the City, *The 2002 Input-Output Study for Hawai'i,* U.S. Census data, the *State of Hawai'i Data Book,* employment and labor rates from the State Department of Labor and Industrial Relations (DLIR), and State and City tax rates.

2011 Dollars

Throughout the report, dollar amounts are expressed in terms of 2011 purchasing power and market conditions. Values, prices, costs and dollar amounts for prior years are adjusted for inflation to 2011 dollars based on the Honolulu Consumer Price Index (CPI) for Urban Consumers. Dollar amounts after 2011 are not increased to account for inflation, appreciation in property values, changes in labor rates, changes in building costs, or other changes in market conditions.

Accuracy of Estimates

Much of the analysis contained in this report is quantitative in nature, where numbers are used to help communicate anticipated impacts. However, these numbers should not be interpreted as precise predictions. Rather, they represent the best estimates of what is expected to occur based on available information about future development, market conditions, and tax rates. Low and high estimates reflect the uncertainty associated with the estimates.

c. Organization of the Report

The material below gives the following information about the Project and its economic and fiscal impacts: a description of the Project, the economic impacts of construction and related activities, the economic impacts of Project operations and related activities, and the impact on State and City finances.

The detailed assumptions, multipliers and calculations are shown in four tables at the end of the report. These tables cover the following:

— Table 1: Proposed Development

— Table 2: Economic Impacts of Construction Activity

— Table 3: Economic Impacts of Operations

— Table 4: Impacts on State and City Finances

The quantities appearing in **bold** in the tables highlight the more significant economic and fiscal impacts.

d. Economic Consultant

The analysis was conducted by Plasch Econ Pacific LLC (PEP), a Hawai‘i-based economic-consulting firm specializing in economic development, land and housing economics, feasibility studies, valuations, market analysis, public policy analysis, and the economic and fiscal impacts of projects.

2. PROJECT DESCRIPTION

Major components of the two conveyance alternatives are summarized in Table 1. As indicated by the Xs in the table, the Force Main alternative will include a force main from Kaneohe to Kailua via a route under Kaneohe Bay, a Kaneohe Equalization Basin, a Kaneohe Effluent Pump Station, and a Kailua Equalization Basin.

The Gravity Tunnel alternative will include a tunnel from Kaneohe to Kailua via a route under Oneawa Hills, an influent pump station at Kaneohe, a Drop Shaft at Kaneohe, an Odor Control Facility at Kaneohe, and Connection Piping to the Kailua Influent Pump Station.

3. ECONOMIC IMPACTS OF CONSTRUCTION

Table 2 summarizes the direct and indirect economic impacts of construction activity. The material in this table gives the development period, construction expenditures, indirect sales generated by the construction activity, employment and payroll, and the number of residents and homes supported by Project construction activity.

a. Construction Period

For both alternatives, the estimated construction period is about 3 years (Table 2, Section 2.a). However, construction could require more or less time, depending on circumstances.

b. Construction Expenditures and Related Sales

<u>Construction Expenditures</u>

Over the 3-year development period, total construction expenditures for the Force Main alternative are estimated at $128 to $224 million (Table 2, Section 2.b). This translates into average construction expenditures of about $42.7 to $74.7 million per year. In practice, construction expenditures will vary from year to year.

For the Gravity Tunnel alternative, total construction expenditures are estimated at $102 to $163 million, or about $34 to $54.3 million per year.

Indirect Sales Generated by Construction Activity

In addition to construction expenditures, construction activity will generate indirect sales associated with supplying goods and services to construction companies and to the families of construction workers. In turn, the companies supplying goods and services, and the families of their employees, will purchase goods and services from other companies, and so on. These indirect sales will include sales by companies that supply building materials (cement, steel, lumber for forms, dynamite, etc.); sell or rent out construction equipment (excavators, cranes, drills, compressors, fans, welding torches, etc.); and provide services (repairs, trucking, shipping, warehousing, etc.). Indirect sales also include sales by grocery stores, drugstores, restaurants, service stations, beauty salons, medical providers, accountants, attorneys, insurance agents, etc.

Based on State economic multipliers, these indirect sales are expected to average $38.7 to $67.6 million per year for the Force Main construction activity, and $30.8 to $49.2 million per year for the Gravity Tunnel construction activity (Table 2, Section 2.b).

Total Construction Expenditures and Indirect Sales

Construction expenditures plus indirect sales generated by construction are expected to average $81.3 to $142.3 million per year for the Force Main alternative, of which $46.9 to $82 million per year will be subject to the State and City 4.5% excise tax on final sales, and $34.4 to $60.3 million per year will be subject to the 0.5% excise tax on intermediate sales. Corresponding annual figures for the Gravity Tunnel alternative are $64.8 to $103.6 million for total construction expenditures and indirect sales, of which $37.4 million to $59.7 million will be subject to the 4.5% tax on final sales, while $27.4 to $43.9 million will be subject to the 0.5% tax on intermediate sales.

c. Profits Related to Construction Activity

Profits on construction and indirect sales are estimated to average $10.3 to 18 million per year for the Force Main construction activity, and $8.2 to $13.1 per year for the Gravity Tunnel construction activity (Table 2, Section 2.c).

d. Construction Employment and Related Jobs

Construction Employment

Over the 3-year construction period, construction employment is expected to average between 55 and 96 jobs for the Force Main alternative, and between 44 and 70 jobs for the

Gravity Tunnel alternative (Table 2, Section 2.d). Construction jobs will include supervisors, heavy-equipment operators, cement workers, iron workers, carpenters, electricians, laborers, etc. Other jobs related to construction will include architects, civil engineers, draftsmen, government inspectors, etc. These jobs will range over a variety of skill levels, including entry-level, semiskilled, skilled, management, and professional positions.

Indirect Employment Generated by Construction Activity

As with indirect sales, construction activity will generate indirect jobs associated with supplying goods and services to construction companies and to the families of construction workers. In turn, the companies supplying goods and services, and the families of their employees will purchase goods and services from other companies, and so on. The jobs will range over a variety of skill levels, including entry-level, semi-skilled, skilled, and management positions.

Based on State employment multipliers, indirect employment related to the Force Main construction activity is expected to average from 77 to 134 jobs, and 62 to 98 jobs for the Gravity Tunnel construction activity.

Total Construction Employment and Indirect Jobs

Total direct-plus-indirect employment associated with the Force Main construction activity will average from 132 to 230 jobs, and 106 to 168 jobs for the Gravity Tunnel construction activity.

e. Payroll Related to Construction Activity

Force Main construction activity is expected to generate a total payroll of $7.7 to $13.4 million per year, of which $4.3 to $7.5 million will be for construction workers and $3.4 to $5.9 million will be for for indirect employment (Table 2, Section 2.d). Corresponding annual figures for the Gravity Tunnel construction activity are $3.4 to $5.4 million for construction workers, and $2.7 to $4.3 million for indirect employment, for a total of about $6.1 to $9.8 million.

Annual wages will range from about $25,000 to over $100,000 per year, and are expected to average about $78,000 for construction jobs, and about $44,200 for indirect jobs.

f. Population and Housing Supported by Construction Activity

During the construction period, direct and indirect jobs provided by the Force Main construction activity will support 274 to 479 residents housed in 91 to 158 homes (Table 2, Section 2.e). Corresponding figures for the Gravity Tunnel construction activity are 221 to 350 residents housed in 73 to 115 homes.

g. Sources of Construction Workers

Except for a small number of specialized supervisors and workers, it is expected that over 90% of the construction workers will come from O‘ahu.

4. ECONOMIC IMPACTS OF OPERATIONS

Table 3 summarizes the economic and related impacts of Project operations, including operating expenditures, indirect sales, employment and payroll, and the population and number of homes that will be supported by operations.

a. Operating Expenditures and Related Sales

Operating Expenditures

Annual operating expenditures are expected to average $1.7 to $2.4 million for the Force Main alternative, and $500,000 to $800,000 for the Gravity Tunnel alternative (Table 3, Section 3.a).

Indirect Sales Generated by Operations

In addition to operating expenditures, operations will generate indirect sales associated with (1) the City’s purchase of goods and services to support operations, and (2) the purchase of goods and services by the families of employees. In turn, the companies supplying goods and services, and the families of their employees, will purchase goods and services from other companies, and so on. These indirect sales will include sales by companies that supply chemicals, electricity, repair services, etc. Indirect sales also include sales by grocery stores, drugstores, restaurants, service stations, beauty salons, medical providers, accountants, attorneys, insurance agents, etc.

Based on State economic multipliers, these indirect sales are expected to average $1.6 to $2.3 million per year for the Force Main alternative, and $400,000 to $700,000 per year for the Gravity Tunnel alternative (Table 3, Section 3.a).

Total Operating Expenditures and Indirect Sales

Operating expenditures plus indirect sales generated by operations are expected to average $3.3 to $4.7 million per year for the Force Main alternative, of which $1.1 to $1.6 million per year will be subject to the State and City 4.5% excise tax on final sales, and $1.1 to $1.5 million per year will be subject to the 0.5% excise tax on intermediate sales. Corresponding annual figures for the Gravity Tunnel alternative are $940,000 to $1.5 million for total operating expenditures and indirect sales, of which $320,000 to $510,000 will be subject to the 4.5% excise tax on final sales, and $300,000 to $480,000 will be subject to the 0.5% excise tax on intermediate sales.

b. Profits Related to Operations

Profits of the companies that provide goods and services to support Project operations and indirect sales are estimated at $220,000 to $310,000 per year for the Force Main alternative, and $60,000 to $100,000 per year for the Gravity Tunnel alternative (Table 3. Section 3.b).

c. Operating Employment and Related Jobs

Operating Employment

Operating employment is expected to range from 13 to 19 employees for the Force Main alternative, and 3 to 5 employees for the Gravity Tunnel alternative (Table 3, Section 3.c).

Indirect Employment Generated by Operations

Additional jobs will be generated by the City's purchase of goods and services to support operations, and the purchase of goods and services by the families of the Project employees. Based on State economic multipliers, these purchases are expected to generate 7 to 10 indirect jobs for the Force Main alternative, and 2 to 3 jobs for the Gravity Tunnel alternative.

Total Operating Employment and Indirect Jobs

Operating employment plus indirect jobs are expected to total 20 to 29 jobs for the Force Main alternative, and 5 to 8 jobs for the Gravity Tunnel alternative.

d. Payroll Related to Operations

Force Main operations are expected to generate a total payroll of $970,000 to $1.4 million per year, of which $660,000 to $940,000 will be for operations employees and $310,000 to $440,000 will be for indirect jobs (Table 3, Section 3.c). Corresponding figures for the Gravity Tunnel operations are $165,000 to $260,000 for operations employees, and $90,000 to $ 130,000 for indirect jobs, for a total of about $250,000 to $400,000 annually.

Annual wages will range from about $25,000 to over $100,000 per year, and are expected to average about $49,800 for operations jobs, and about $44,200 for indirect jobs.

e. Population and Housing Supported by Operations

Direct and indirect jobs provided by the Force Main operations activity will support 42 to 61 residents housed in 14 to 20 homes (Table 3, Section 3.d). Corresponding figures for the Gravity Tunnel operations activity are 10 to 16 residents housed in 3 to 5 homes.

f. Sources of Operating Workers

Most workers for Project operations will be drawn from existing positions within the City's Department of Environmental Services, including positions associated with the existing wastewater conveyance and treatment facilities in Kaneohe and Kailua.

5. IMPACTS ON STATE AND CITY FINANCES

Table 4 shows the impact of the Project on State and City tax revenues, including the change in the tax bases, tax revenues generated by construction activity, and tax revenues generated by Project operations.

a. Impacts of Construction Activity on State and City Finances

State

Force Main construction is projected to generate $7.6 to $13.2 million in tax revenues for the State, while Gravity Tunnel construction is projected to generate $6 to $9.6 million in revenues (Table 4, Section 4.b). State revenues will be derived from excise taxes on final and intermediate sales (taxed at 4% and 0.5%, respectively), and from corporate and personal income taxes.

State services for construction workers and their families are, for the most part, already provided since most of the needed construction workers are current residents of Oʻahu.

City

For the City, Force Main construction is projected to generate $700,000 to $1.2 million in tax revenues, while Gravity Tunnel construction is projected to generate $560,000 to $900,000. City revenues will be derived from the 0.5% excise tax on final sales that helps fund the rapid transit system.

As with the State, City services for construction workers and their families are already provided since most of the needed construction workers are current residents of Oʻahu. Also, the City will not incur costs for on-site security, sanitation, etc., since these services will be provided by the construction companies.

b. Impacts of Operations on State and City Finances

State

For the Force Main alternative, Project operations will generate $100,000 to $140,000 per year in tax revenues to the State (Table 4, Section 3.c). Corresponding figures for the Gravity Tunnel alternative are $30,000 to $40,000 per year. State revenues will be derived from excise taxes on final and intermediate sales (taxed at 4% and 0.5%, respectively), and from corporate and personal income taxes.

The revenues will help fund State services to those residents supported by Project operations.

City

For the Force Main alternative, Project operations will generate $5,000 to $8,000 per year in tax revenues to the City, while the Gravity Tunnel operations will generate $1,500 to $2,500 per year. City revenues will be derived from the 0.5% excise tax on final sales that helps fund the rapid transit system.

6. REFERENCES

Wilson Okamoto Corporation. 2010.

City and County of Honolulu. Ordinance 09-11, Bill 15 (2009), CD2, FD1.

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Real Property Assessment Division, City & County of Honolulu. 2010.

Tax Foundation of Hawai’i. “Taxes in Hawai’i.” Annual.

U.S. Census. 2000.

Table 1. Proposed Development
(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
1.a. ALTERNATIVES AND MAJOR COMPONENTS						
Force Main Alternative	WO	X	X			
Sewer Main, Kaneohe to Kailua under Kaneohe Bay		X	X			
Kaneohe Equalization Basin		X	X			
Kaneohe Effluent Pump Station		X	X			
Kailua Equalization Basin		X	X			
Gravity Tunnel Alternative	WO					
Tunnel, Kaneohe to Kailua under Oneawa Hills				X	X	
Kaneohe Influent Pump Station				X	X	
Kaneohe Drop Shaft				X	X	
Kaneohe Odor Control Facility				X	X	
Kailua Connection Piping to Influent Pump Station				X	X	

Table 2. Economic Impacts of Construction

(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
2.a. DURATION OF CONSTRUCTION	Wilson Okamoto	3	3	3	3	**years**
2.b. CONSTRUCTION EXPENDITURES AND RELATED SALES						
Construction Expenditures						
Conveyance System	WO	$ 54,000,000	$ 118,000,000	$ 82,000,000	$ 133,000,000	
Kaneohe Equalization Basin	"	$ 47,000,000	$ 67,000,000			
Kaiula Equalization Basin	"	$ 27,000,000	$ 39,000,000			
Influent Pump Station	"			$ 20,000,000	$ 30,000,000	
Total Construction Expenditures		**$ 128,000,000**	**$ 224,000,000**	**$ 102,000,000**	**$ 163,000,000**	
Construction Expenditures, Annual Average		**$ 42,666,667**	**$ 74,666,667**	**$ 34,000,000**	**$ 54,333,333**	**per year**
Indirect Sales Generated by Construction	151% of const. exp. x 60% for Hawaii exp.	$ 38,656,000	$ 67,648,000	$ 30,804,000	$ 49,226,000	"
Total Annual Expenditures and Sales		**$ 81,322,667**	**$ 142,314,667**	**$ 64,804,000**	**$ 103,559,333**	**per year**
Final Sales (taxed at 4.5%)						
Construction Expenditures	repeated from above	$ 42,666,667	$ 74,666,667	$ 34,000,000	$ 54,333,333	per year
Consumption	55% of payroll Section 2.d	$ 4,218,537	$ 7,364,207	$ 3,377,220	$ 5,370,713	"
Total Sales at 4.5%		$ 46,885,204	$ 82,030,874	$ 37,377,220	$ 59,704,046	per year
Intermediate Sales (taxed at 0.5%)						
Indirect Sales Generated by Construction	repeated from above	$ 38,656,000	$ 67,648,000	$ 30,804,000	$ 49,226,000	"
Less Consumption	"	$ (4,218,537)	$ (7,364,207)	$ (3,377,220)	$ (5,370,713)	"
Total Sales at 0.5%		$ 34,437,463	$ 60,283,793	$ 27,426,780	$ 43,855,287	per year
2.c. PROFITS						
Profits on Total Expenditures & Sales	10.0% of total sales	$ 8,132,267	$ 14,231,467	$ 6,480,400	$ 10,355,933	per year
Risk Premium for Construction	5.0% of const. exp.	$ 2,133,333	$ 3,733,333	$ 1,700,000	$ 2,716,667	"
Total Profit from Construction & Related Activity		$ 10,265,600	$ 17,964,800	$ 8,180,400	$ 13,072,600	per year

Table 2. Economic Impacts of Construction

(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
2.d. EMPLOYMENT AND PAYROLL						
Employment						
Construction Jobs (including subcontractors)	$ 78,000 per job	**55**	**96**	**44**	**70**	**jobs**
Indirect Jobs	1.40 x direct jobs	77	134	62	98	"
Total Employment		**132**	**230**	**106**	**168**	**jobs**
Payroll						
Construction Payroll	10% of const. exp.	**$ 4,266,667**	**$ 7,466,667**	**$ 3,400,000**	**$ 5,433,333**	**per year**
Indirect Employment Payroll	$ 44,200 per job	$ 3,403,400	$ 5,922,800	$ 2,740,400	$ 4,331,600	"
Total Payroll		**$ 7,670,067**	**$ 13,389,467**	**$ 6,140,400**	**$ 9,764,933**	**per year**
2.e. POPULATION AND HOUSING SUPPORTED BY CONSTRUCTION ACTIVITY						
Population Supported						
Supported by Construction Jobs	2.08 per job	114	200	92	146	residents
Supported by Indirect Jobs	2.08 "	160	279	129	204	"
Total Residents		**274**	**479**	**221**	**350**	**residents**
Housing Supported						
Supported by Construction Jobs	0.33 per resident	38	66	30	48	homes
Supported by Indirect Jobs	0.33 "	53	92	43	67	"
Total Homes		**91**	**158**	**73**	**115**	**homes**

Table 1. Proposed Development
(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
1.a. ALTERNATIVES AND MAJOR COMPONENTS						
Force Main Alternative	WO	X	X			
Sewer Main, Kaneohe to Kailua under Kaneohe Bay		X	X			
Kaneohe Equalization Basin		X	X			
Kaneohe Effluent Pump Station		X	X			
Kailua Equalization Basin		X	X			
Gravity Tunnel Alternative	WO					
Tunnel, Kaneohe to Kailua under Oneawa Hills				X	X	
Kaneohe Influent Pump Station				X	X	
Kaneohe Drop Shaft				X	X	
Kaneohe Odor Control Facility				X	X	
Kailua Connection Piping to Influent Pump Station				X	X	

Table 2. Economic Impacts of Construction

(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
2.a. DURATION OF CONSTRUCTION	Wilson Okamoto	**3**	**3**	**3**	**3**	**years**
2.b. CONSTRUCTION EXPENDITURES AND RELATED SALES						
Construction Expenditures						
Conveyance System	WO	$ 54,000,000	$ 118,000,000	$ 82,000,000	$ 133,000,000	
Kaneohe Equalization Basin	"	$ 47,000,000	$ 67,000,000			
Kaiula Equalization Basin	"	$ 27,000,000	$ 39,000,000			
Influent Pump Station	"			$ 20,000,000	$ 30,000,000	
Total Construction Expenditures		**$ 128,000,000**	**$ 224,000,000**	**$ 102,000,000**	**$ 163,000,000**	
Construction Expenditures, Annual Average		**$ 42,666,667**	**$ 74,666,667**	**$ 34,000,000**	**$ 54,333,333**	**per year**
Indirect Sales Generated by Construction	151% of const. exp. x 60% for Hawaii exp.	$ 38,656,000	$ 67,648,000	$ 30,804,000	$ 49,226,000	"
Total Annual Expenditures and Sales		**$ 81,322,667**	**$ 142,314,667**	**$ 64,804,000**	**$ 103,559,333**	**per year**
Final Sales (taxed at 4.5%)						
Construction Expenditures	repeated from above	$ 42,666,667	$ 74,666,667	$ 34,000,000	$ 54,333,333	per year
Consumption	55% of payroll Section 2.d	$ 4,218,537	$ 7,364,207	$ 3,377,220	$ 5,370,713	"
Total Sales at 4.5%		$ 46,885,204	$ 82,030,874	$ 37,377,220	$ 59,704,046	per year
Intermediate Sales (taxed at 0.5%)						
Indirect Sales Generated by Construction	repeated from above	$ 38,656,000	$ 67,648,000	$ 30,804,000	$ 49,226,000	"
Less Consumption	"	$ (4,218,537)	$ (7,364,207)	$ (3,377,220)	$ (5,370,713)	"
Total Sales at 0.5%		$ 34,437,463	$ 60,283,793	$ 27,426,780	$ 43,855,287	per year
2.c. PROFITS						
Profits on Total Expenditures & Sales	10.0% of total sales	$ 8,132,267	$ 14,231,467	$ 6,480,400	$ 10,355,933	per year
Risk Premium for Construction	5.0% of const. exp.	$ 2,133,333	$ 3,733,333	$ 1,700,000	$ 2,716,667	"
Total Profit from Construction & Related Activity		$ 10,265,600	$ 17,964,800	$ 8,180,400	$ 13,072,600	per year

Table 2. Economic Impacts of Construction

(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
2.d. EMPLOYMENT AND PAYROLL						
Employment						
Construction Jobs (including subcontractors)	$ 78,000 per job	**55**	**96**	**44**	**70**	**jobs**
Indirect Jobs	1.40 x direct jobs	77	134	62	98	"
Total Employment		**132**	**230**	**106**	**168**	**jobs**
Payroll						
Construction Payroll	10% of const. exp.	**$ 4,266,667**	**$ 7,466,667**	**$ 3,400,000**	**$ 5,433,333**	**per year**
Indirect Employment Payroll	$ 44,200 per job	$ 3,403,400	$ 5,922,800	$ 2,740,400	$ 4,331,600	"
Total Payroll		**$ 7,670,067**	**$ 13,389,467**	**$ 6,140,400**	**$ 9,764,933**	**per year**
2.e. POPULATION AND HOUSING SUPPORTED BY CONSTRUCTION ACTIVITY						
Population Supported						
Supported by Construction Jobs	2.08 per job	114	200	92	146	residents
Supported by Indirect Jobs	2.08 "	160	279	129	204	"
Total Residents		**274**	**479**	**221**	**350**	**residents**
Housing Supported						
Supported by Construction Jobs	0.33 per resident	38	66	30	48	homes
Supported by Indirect Jobs	0.33 "	53	92	43	67	"
Total Homes		**91**	**158**	**73**	**115**	**homes**

Table 3. Economic Impacts of Operations
(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
3.a. OPERATING EXPENDITURES AND RELATED SALES						
Operating Expenditures						
Labor, Material and Services (LM&S)	residual	$ 1,496,000	$ 2,112,000	$ 330,000	$ 528,000	per year
Electrical Energy, Force Main	12% of total	$ 204,000	$ 288,000			"
Electrical Energy, Gravity Tunnel	34% "			$ 170,000	$ 272,000	"
Total Operating Expenditures	PEP and WO	**$ 1,700,000**	**$ 2,400,000**	**$ 500,000**	**$ 800,000**	**per year**
Indirect Sales Generated by Operations						
from Labor, Material and Services	98% of LM&S	$ 1,466,080	$ 2,069,760	$ 323,400	$ 517,440	"
from Electrical Energy	68% of electrical	$ 138,720	$ 195,840	$ 115,600	$ 184,960	"
Total Indirect Sales		$ 1,604,800	$ 2,265,600	$ 439,000	$ 702,400	per year
Total Expenditures and Sales		**$ 3,304,800**	**$ 4,665,600**	**$ 939,000**	**$ 1,502,400**	**per year**
Final Sales (taxed at 4.5%)						
Taxed Purchases, Force Main	36% of operating exp.	$ 612,000	$ 864,000	$ 180,000	$ 288,000	per year
Consumption	55% of payroll Section 3.b	$ 534,820	$ 757,900	$ 139,370	$ 218,130	"
Total Final Sales		$ 1,146,820	$ 1,621,900	$ 319,370	$ 506,130	per year
Intermediate Sales (taxed at 0.5%)						
Indirect Sales Related to Operations	repeated from above	$ 1,604,800	$ 2,265,600	$ 439,000	$ 702,400	per year
less Consumption	"	$ (534,820)	$ (757,900)	$ (139,370)	$ (218,130)	"
Total Intermediate Sales		$ 1,069,980	$ 1,507,700	$ 299,630	$ 484,270	per year

Table 3. Economic Impacts of Operations
(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
3.b. PROFITS						
Profits on Final Sales	10% of final sales	$ 114,682	$ 162,190	$ 31,937	$ 50,613	per year
Profits on Indirect Sales	10% of int. sales	$ 106,998	$ 150,770	$ 29,963	$ 48,427	"
Total Profits		**$ 221,680**	**$ 312,960**	**$ 61,900**	**$ 99,040**	**per year**
3.c. EMPLOYMENT AND PAYROLL						
Employment						
Operating Jobs (including subcontractors)	$ 49,800 per job	**13**	**19**	**3**	**5**	**jobs**
Indirect Jobs	53% x direct jobs	7	10	2	3	"
Total Employment		**20**	**29**	**5**	**8**	**jobs**
Payroll						
Operating Payroll, Force Main	39% of operating exp.	**$ 663,000**	**$ 936,000**			**per year**
Operating Payroll, Gravity Tunnel	33% "			**$ 165,000**	**$ 264,000**	
Indirect Employment, Payroll	$ 44,200 per job	$ 309,400	$ 442,000	$ 88,400	$ 132,600	"
Total Payroll		**$ 972,400**	**$ 1,378,000**	**$ 253,400**	**$ 396,600**	**per year**
3.d. POPULATION AND HOUSING SUPPORTED BY OPERATIONS						
Population Supported						
Supported by Operating Jobs	2.08 per job	27	40	6	10	residents
Supported by Indirect Jobs	2.08 "	15	21	4	6	"
Total Residents		**42**	**61**	**10**	**16**	**residents**
Housing Supported						
Supported by Operating Jobs	0.33 per resident	9	13	2	3	homes
Supported by Indirect Jobs	0.33 "	5	7	1	2	"
Total Homes		**14**	**20**	**3**	**5**	**homes**

Table 4. Impacts on State and County Finances

(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
4.a. TAX BASE						
Construction Activity						
Duration	Table 2, Section 2.a	3	3	3	3	years
Final Sales						
Annual Average	Table 2, Section 2.b.	$ 46,885,204	$ 82,030,874	$ 37,377,220	$ 59,704,046	per year
Cumulative		$ 140,655,612	$ 246,092,622	$ 112,131,660	$ 179,112,138	
Intermediate Sales						
Annual Average	Table 2, Section 2.b	$ 34,437,463	$ 60,283,793	$ 27,426,780	$ 43,855,287	per year
Cumulative		$ 103,312,389	$ 180,851,379	$ 82,280,340	$ 131,565,861	
Profits						
Annual Average	Table 2, Section 2.c	$ 10,265,600	$ 17,964,800	$ 8,180,400	$ 13,072,600	per year
Cumulative		$ 30,796,800	$ 53,894,400	$ 24,541,200	$ 39,217,800	
Payroll						
Annual Average	Table 2, Section 2.d	$ 7,670,067	$ 13,389,467	$ 6,140,400	$ 9,764,933	per year
Cumulative		$ 23,010,201	$ 40,168,401	$ 18,421,200	$ 29,294,799	
Operations						
Final Sales	Table 3, Section 3.a	$ 1,146,820	$ 1,621,900	$ 319,370	$ 506,130	per year
Intermediate Sales	"	$ 1,069,980	$ 1,507,700	$ 299,630	$ 484,270	"
Profits (on-site activities)	Table 3, Section 3.b	$ 221,680	$ 312,960	$ 61,900	$ 99,040	"
Payroll	Table 3, Section 3.c	$ 972,400	$ 1,378,000	$ 253,400	$ 396,600	"

Table 4. Impacts on State and County Finances
(Values in 2011 dollars)

Item	Source or Multiplier	Force Main		Gravity Tunnel		Units
		Low	High	Low	High	
4.b. TAX REVENUES FROM CONSTRUCTION ACTIVITY						
State Revenues, Cumulative						
Excise Tax						
Final Sales	4.0% of final sales	$ 5,626,224	$ 9,843,705	$ 4,485,266	$ 7,164,486	
Intermediate Sales	0.5% of int. sales	$ 516,562	$ 904,257	$ 411,402	$ 657,829	
Corporate Income Taxes	1.0% of profits	$ 307,968	$ 538,944	$ 245,412	$ 392,178	
Personal Income Taxes	4.8% of income	$ 1,104,490	$ 1,928,083	$ 884,218	$ 1,406,150	
Total State Tax Revenues		**$ 7,555,244**	**$ 13,214,989**	**$ 6,026,298**	**$ 9,620,643**	
City Revenues, Cumulative						
Excise Tax on Final Sales (for transit)	0.5% of final sales	**$ 703,278**	**$ 1,230,463**	**$ 560,658**	**$ 895,561**	
4.c. TAX REVENUES FROM OPERATIONS						
State Revenues, Annual						
Excise Tax						
from Final Sales (taxed at 4.5%)	4.0% of final sales	$ 45,873	$ 64,876	$ 12,775	$ 20,245	per year
from Intermediate Sales (taxed at 0.5%)	0.5% of int. sales	$ 5,350	$ 7,539	$ 1,498	$ 2,421	"
Corporate Income Tax	1.0% of profit	$ 2,217	$ 3,130	$ 619	$ 990	"
Personal Income Tax	4.8% income	$ 46,675	$ 66,144	$ 12,163	$ 19,037	"
Total State Tax Revenues		**$ 100,115**	**$ 141,689**	**$ 27,055**	**$ 42,693**	**per year**
City Revenues, Annual						
Excise Tax on Final Sales (for rapid transit)	0.5% of final sales	**$ 5,734**	**$ 8,110**	**$ 1,597**	**$ 2,531**	**per year**

Appendix J

Air Quality Study for the Proposed Kaneohe / Kailua Force Main No. 2 Project

B.D. Neal and Associates, April 2010

AIR QUALITY STUDY

FOR THE PROPOSED

KANEOHE/KAILUA FORCE MAIN NO. 2 PROJECT

OAHU, HAWAII

Prepared for:

Austin, Tsutsumi & Associates, Inc.

April 2010

B.D. NEAL & ASSOCIATES

*Applied Meteorology * Air Quality * Computer Science*

P.O. BOX 1808 * KAILUA-KONA, HAWAII 96745 * TELEPHONE (808) 329-1627 * FAX (808) 331-8428
EMAIL: bdneal@kona.net

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1.0 SUMMARY

The City and County of Honolulu is proposing to construct the Kaneohe/Kailua Force Main No. 2 Project at Kaneohe Bay, Oahu. The new force main will originate at the Kaneohe Wastewater Pre-Treatment Facility on the southwest side of the bay and terminate at the Kailua Regional Wastewater Treatment Plant on the northeast side of the bay. The majority of the new force main will be installed under the bay using trenchless methods. It is anticipated that active construction work would occur during a two-year period. This study examines the potential short- and long-term air quality impacts that could occur as a result of construction and use of the proposed facilities and suggests mitigative measures to reduce any potential air quality impacts where possible and appropriate.

Both federal and state standards have been established to maintain ambient air quality. At the present time, seven parameters are regulated including: particulate matter, sulfur dioxide, hydrogen sulfide, nitrogen dioxide, carbon monoxide, ozone and lead. Hawaii air quality standards are comparable to the national standards except those for nitrogen dioxide and carbon monoxide which are more stringent than the national standards. State and federal ambient air quality standards do not generally protect the public from nuisance odor issues. The standards are primarily intended to provide health protection for sensitive elements of the population. Nuisance odor concentrations typically occur at even lower concentrations.

Regional and local climate together with the amount and type of human activity generally dictate the air quality of a given location. The climate of the Kaneohe Bay area is very much affected by the topography of the island and its coastal situation. Winds are predominantly trade winds from the east northeast except for occasional periods when kona storms may generate strong winds from the south or when the trade winds are weak and landbreeze-seabreeze or drainage flow circulations may develop. Wind speeds average about 8 miles per hour providing relatively good ventilation much of the time. Temperatures in the area are generally very moderate with average daily temperatures ranging from about 68°F to 79°F. Average annual rainfall in the project area amounts to about 50 to 60 inches with summer months usually being the wettest.

Although there is very little air quality data available from the Department of Health for the windward areas of the island of Oahu, the present air quality of the project area appears to be reasonably good. Based on the information available, it appears likely that all national air quality standards are currently being met, although occasional exceedances of the more stringent state standards for carbon monoxide may occur near congested roadway intersections.

If the proposed project is given the necessary approvals to proceed, it may be inevitable that some short-term impacts on air quality will occur either directly or indirectly as a consequence of project construction. An evaluation of the project emissions during construction suggests that particulate emissions (primarily fugitive dust) would likely be considered significant, while emissions of other air pollutants from diesel fuel usage and from other construction-related activities would likely be insignificant. Short-term impacts from fugitive dust will likely occur during the two-year project construction schedule, and to a lesser extent, exhaust emissions from stationary and mobile construction equipment, from the disruption of traffic, and from workers' vehicles may also affect air quality for a period of time and/or intermittently during the period of construction. State air pollution control regulations require that there be no visible fugitive dust emissions at the property line. Hence, an effective dust control plan must be implemented to ensure compliance with state regulations. Fugitive dust emissions can be controlled to a large extent by watering of active work areas, using wind screens, keeping adjacent paved roads clean, and by covering of open-bodied trucks. Other dust control measures could include limiting the area that can be disturbed at any given time and/or mulching or chemically stabilizing inactive areas that have been worked. Monitoring dust at the project boundary during the period of construction could be considered as a means to evaluate the effectiveness of the project dust control program. Exhaust emissions can be mitigated by moving construction equipment and workers to and from the project site during off-peak traffic hours and by ensuring that all construction equipment is well maintained.

After construction is completed, it is expected that the new force main would not result in any long-term air pollution emissions or impacts on air quality.

2.0 INTRODUCTION

The City and County of Honolulu (City) is proposing to construct the Kaneohe/Kailua Force Main No. 2 Project in the Kaneohe Bay area on the island of Oahu (see Figure 1 for general project location). The project involves the installation of approximately 14,150 feet to 14,600 feet of force main between the Kaneohe Wastewater Pre-Treatment Facility and the Kailua Regional Wastewater Treatment Plant. The majority of the new force main traverse under Kaneohe Bay.

The purpose of this study is to describe existing air quality in the project area and to assess the potential short- and long-term direct and indirect air quality impacts that could result from construction and use of the proposed facilities as planned. Measures to mitigate project impacts are suggested where possible and appropriate.

3.0 AMBIENT AIR QUALITY STANDARDS

Ambient concentrations of air pollution are regulated by both national and state ambient air quality standards (AAQS). National AAQS are specified in Section 40, Part 50 of the Code of Federal Regulations (CFR), while State of Hawaii AAQS are defined in Chapter 11-59 of the Hawaii Administrative Rules. Table 1 summarizes both the national and the state AAQS that are specified in the cited documents. As indicated in the table, national and state AAQS have been established for particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone and lead. The state has also set a standard for hydrogen sulfide. National AAQS are stated in terms of both primary and secondary standards for most of the regulated air pollutants. National primary standards are designed to protect the public health with an "adequate margin of safety". National secondary standards, on the other hand, define levels of air quality necessary to protect the public welfare from "any known or anticipated adverse effects of a pollutant". Secondary public welfare impacts may include such effects as decreased visibility, diminished comfort levels, or other potential injury to the natural or man-made environment, e.g., soiling of materials, damage to vegetation or other economic damage. In contrast to the national AAQS, Hawaii State AAQS are given in terms of a single standard that is designed "to protect public health and welfare and to prevent the significant deterioration of air quality".

Each of the regulated air pollutants has the potential to create or exacerbate some form of adverse health effect or to produce environmental degradation when present in sufficiently high concentration for prolonged periods of time. The AAQS specify a maximum allowable concentration for a given air pollutant for one or more averaging times to prevent harmful effects. Averaging times vary from one hour to one year depending on the pollutant and type of exposure necessary to cause adverse effects. In the case of the short-term (i.e., 1- to 24-hour) AAQS, both national and state standards allow a specified number of exceedances each year.

The Hawaii AAQS are in some cases considerably more stringent than the comparable national AAQS. In particular, the Hawaii 1-hour AAQS for carbon monoxide is four times more stringent than the comparable national limit.

The Hawaii AAQS for sulfur dioxide were relaxed in 1986 to make the state standards essentially the same as the national limits. In 1993, the state also revised its particulate standards to follow those set by the federal government. During 1997, the federal government again revised its standards for particulate, but the new standards were challenged in federal court. A Supreme Court ruling was issued during February 2001, and as a result, the new standards for particulate were finally implemented during 2005. To date, the Hawaii Department of Health has not updated the state particulate standards. In September 2001, the state vacated the state 1-hour standard for ozone and an 8-hour standard was adopted.

During the latter part of 2008, EPA revised the standard for lead making the standard more stringent. So far, the Hawaii Department of Health has not revised the corresponding state standard for lead. Most recently (January 2010), a national 1-hour standard for nitrogen dioxide was implemented.

4.0 REGIONAL AND LOCAL CLIMATOLOGY

Regional and local climatology significantly affect the air quality of a given location. Wind, temperature, atmospheric turbulence, mixing height and rainfall all influence air quality. Although the climate of Hawaii is relatively moderate throughout most of the state and most of the year, significant differences in these parameters may occur from one location to another. Most differences in regional and local climates within the state are caused by the mountainous topography.

Hawaii lies well within the belt of northeasterly trade winds generated by the semi-permanent Pacific high pressure cell to the north and east. On the island of Oahu, the Koolau and Waianae Mountain Ranges are oriented almost perpendicular to the trade winds, which accounts for much of the variation in the local climatology of the island. The Kaneohe Bay area, the site of the proposed project, is located on the windward side of Oahu at the foot of the steep Koolaus and is thus directly exposed to the trade winds.

The nearest long-term wind data available for the project area were collected at the Kaneohe Marine Corps Base Hawaii which is located at Kaneohe Bay. These data should be very representative of the project area. As indicated in Table 2, the mean annual wind speed is 8.4 mph and the annual prevailing wind direction for this area of Oahu is east northeast. Monthly average wind speeds and directions are similar to the annual averages. Ventilation typically is relatively good year round. In winter, the intensity of the trade winds diminishes and the passage of storms can bring very strong "kona" winds for brief periods from the south or southwest, but the Kaneohe Bay area is largely sheltered from kona winds by the terrain. When trade winds or kona winds are absent or weak, local winds such as land/sea breezes and/or upslope/downslope winds tend to dominate the wind pattern for the area. During such times, light winds typically move onshore from the east during the daytime because of seabreeze and/or upslope effects and at night and during the early morning hours land breezes and/or drainage winds move downslope from the west or southwest and out to sea.

Air pollution emissions from motor vehicles, the formation of photochemical smog and smoke plume rise all depend in part on air temperature. Colder temperatures tend to result in higher emissions of contaminants from automobiles but lower concentrations of photochemical smog and ground-level concentrations of air pollution from elevated plumes. In Hawaii, the annual and daily variation of temperature depends to a large degree on elevation above sea level, distance inland and exposure to the trade winds. Average temperatures at locations near sea level generally are warmer than those at higher elevations. Areas exposed to the trade wind tend to have the least temperature variation, while inland and leeward areas often have the most. On the windward side of Oahu at Kaneohe, daily temperatures range between 68°F and 79°F on the average while the extremes range from 54°F to 93°F [1].

Small scale, random motions in the atmosphere (turbulence) cause air pollutants to be dispersed as a function of distance or time from the point of emission. Turbulence is caused by both mechanical and thermal forces in the atmosphere. It is oftentimes measured and described in terms of Pasquill-Gifford stability class. Stability class 1 is the most turbulent and class 6 the least. Thus, air pollution dissipates the best during stability class 1 conditions and the worst when stability class 6 prevails. In the Kaneohe Bay area, stability class 5 or 6 is generally the highest stability class that occurs, developing during clear, calm nighttime or early morning hours when temperature inversions form either due to radiational cooling or to downslope winds that push warmer air aloft. Stability classes 1 through 4 occur during the daytime, depending mainly on the amount of cloud cover and incoming solar radiation and the onset and extent of the sea breeze.

Mixing height is defined as the height above the surface through which relatively vigorous vertical mixing occurs. Low mixing heights can result in high ground-level air pollution concentrations because contaminants emitted from or near the surface can become trapped within the mixing layer. In Hawaii, minimum mixing heights tend to be high because of mechanical mixing caused by the trade winds and because of the temperature moderating effect of the surrounding ocean. Low mixing heights may sometimes occur, however, at inland locations and even at times along coastal areas early in the morning following a clear, cool, windless night. Coastal areas may also experience low mixing levels during sea breeze conditions when cooler ocean air rushes in over warmer land. Although there are no mixing height data for the Kailua area, mixing heights elsewhere in the state typically are above 3000 feet (1000 meters). Mixing heights in the Kailua area probably tend to be somewhat lower during periods of light winds and also during periods when sea breeze conditions develop during the daytime.

Rainfall can have a beneficial effect on the air quality of an area in that it helps to suppress fugitive dust emissions, and it also may "washout" gaseous contaminants that are water soluble. Rainfall in Hawaii is highly variable depending on elevation and on location with respect to the trade wind. In the Kailua-Kaneohe area, rainfall is moderate amounting to about 50 to 60 inches per year. The summer months are usually the wettest.

5.0 PRESENT AIR QUALITY

Present air quality in the project area is mostly affected by air pollutants from motor vehicles, industrial sources, military facilities, agricultural operations and to a lesser extent by natural sources. Table 3 presents an air pollutant emission summary for the island of Oahu for calendar year 1993. This is the latest information that is available. Although it has become dated, some useful information may still be derived from it. The emission rates shown in the table pertain to manmade emissions only, i.e., emissions from natural sources are not included. As suggested in the table, much of the particulate emissions on Oahu originate from area sources, such as the mineral products industry and agriculture. Sulfur oxides are emitted almost exclusively by point sources, such as power plants and refineries. Nitrogen oxides emissions emanate predominantly from industrial point sources, although area sources (mostly motor vehicle traffic) also contribute a significant share. The majority of carbon monoxide emissions occur from area sources (motor vehicle traffic), while hydrocarbons are emitted mainly from point sources. Based on previous emission inventories that have been reported for Oahu, emissions of particulate and nitrogen oxides may have increased during the past several years, while emissions of sulfur oxides, carbon monoxide and hydrocarbons probably have declined.

The State Department of Health operates a network of air quality monitoring stations at several locations on Oahu, although all of the stations are located in leeward areas. Data from some of these stations are summarized in Table 4. Table 4 shows annual summaries of air quality measurements that were made at selected stations for several of the regulated air pollutants for the period 2004 through 2008. These are the most recent data that are currently available.

During the 2004-2008 period, sulfur dioxide was monitored by the State Department of Health at an air quality station located in downtown Honolulu. Concentrations monitored were consistently low compared to the standards. Annual second-highest 3-hour concentrations (which are most relevant to the air quality standards) ranged from 36 to 57 $\mu g/m^3$, while the annual second-highest 24-hour concentrations ranged from 5 to 18 $\mu g/m^3$. Annual average concentrations were only about 1 to 3 $\mu g/m^3$. These values represent only about 5 percent or less of the allowable maximum concentrations. There were no exceedances of the state/national 3-hour or 24-hour AAQS for sulfur dioxide during the 5-year period.

Particulate matter less than 10 microns in diameter (PM-10) is also measured at the Honolulu monitoring station. Annual second-highest 24-hour PM-10 concentrations ranged from 23 to 35 $\mu g/m^3$ between 2004 and 2008. Average annual concentrations ranged from 13 to 15 $\mu g/m^3$. These values are less than about 30 percent of the allowable concentrations. All values reported were within the state and national AAQS.

Carbon monoxide measurements were also made at the Honolulu monitoring station. The annual second-highest 1-hour concentrations ranged from 1.8 to 3.1 mg/m^3. The annual second-highest 8-hour concentrations ranged from 1.2 to 1.6 mg/m^3. These values represent about 30 percent or less of the allowable concentrations. No exceedances of the state or national 1-hour or 8-hour AAQS were reported.

Nitrogen dioxide is monitored by the Department of Health at the Kapolei monitoring station. Annual average concentrations of this pollutant ranged from 8 to 9 $\mu g/m^3$, safely inside the state AAQS of 70 $\mu g/m^3$.

The nearest available ozone measurements were obtained at Sand Island. The second-highest 8-hour concentrations for the 2004-2008 monitoring period ranged from 69 to 108 $\mu g/m^3$. These concentrations are within the state and federal standards which limit the three-year average of the fourth-highest value to 157 $\mu g/m^3$.

Although not shown in the table, the nearest and most recent measurements of ambient lead concentrations that have been reported were made at the downtown Honolulu monitoring station between 1996 and 1997. Average quarterly concentrations were near or below the detection limit, and no exceedances of the state AAQS were recorded. Monitoring for this parameter was discontinued during 1997.

Air quality in the project area is likely better than that measured at leeward locations because of the windward situation. Thus, although there is no specific air quality monitoring data for the project area, it is probable that the present air quality is within standards except perhaps for small areas around industrial sources or near traffic congested locations.

6.0 PROJECT IMPACTS ON AIR QUALITY

Impacts on air quality are generally classified as either short-term or long-term. For a project of this nature, there will only be short-term impacts which occur during the period of construction. After construction is completed, it is not anticipated that there will be any long-term impacts from air pollution emissions from the constructed facilities.

As described in the Design Alternatives Report (DAR) [2], various alternatives for project design and construction were considered. After due consideration, it was recommended that Alternative 2 be pursued. Alternative 2 involves the installation of approximately 11,000 feet of pipe under the Kaneohe Bay mud line by utilizing trenchless methods of pipe installation. Three options are being considered for construction of this alternative:

- horizontal directional drilling (HDD)
- microtunneling
- tunneling using a slurry tunnel boring machine with the installation of a segmental reinforced concrete liner.

In all three of these options, the new force main would commence at the Kaneohe Effluent Pump Station (EPS) and would traverse through the Kaneohe WWPTF under the paved access road near the eastern boundary for approximately 600 feet. At the facility's north boundary, the force main would traverse within the large parcel owned by Bay View LLC and under the graveled roadway parallel to Kaneohe Stream and adjacent to the Waikalua Loko Fish Pond for another 600 feet. The force main would enter Kaneohe Bay at the shoreline within the peninsula between Kaneohe Stream and the Waikalua Loko Fish Pond and would traverse under Kaneohe Bay for approximately 11,000 feet. The Kaneohe Bay Drive/H-3 Freeway Interchange would serve as the bay exit landing area. Finally, the force main would traverse within Kaneohe Bay Drive for 1,850 feet and terminate at the Kailua RWWTP.

The initial 1,200 feet of pipe commencing at the Kaneohe EPS would be installed by open trench construction. This is also true of the final 1,850 feet of pipe from the Kaneohe Bay Drive/H-3 Freeway Interchange to the Kailua RWWTP. The open trench construction would involve the use of earth excavation equipment which will burn diesel fuel. The combustion of diesel fuel will result in the emissions of nitrogen oxides, carbon monoxide, sulfur oxides, particulate matter and smaller amounts of other contaminants. The open trench work will also result in fugitive particulate (dust) emissions generated by the movement of excavation equipment and trucks and by the handling of soil and rock. During dry, windy periods, wind-blown dust from both active and inactive work areas may also occur.

The placement of pipe under the Kaneohe Bay mud line using trenchless methods will also involve the use of large, diesel equipment both onshore and offshore. In the HDD option, the HDD drill rig will be supported over the bay by pile-supported steel platforms or large spud barges. Other equipment that will likely be involved in the HDD option would include: bentonite mud rig, excavator, backhoe, forklift, 25-ton crane, two generators, vacuum truck, 5-ton dump truck, semi-truck and flatbed trailer, various work trucks and fuel storage facilities. In the microtunneling option, a microtunneling jacking shaft and work platform would be supported over the water. Other equipment used in this option would likely include: microtunnel boring machine, bentonite mixing plant, slurry separation plant, slurry charge and discharge pumps, excavator, backhoe, forklift, crane, two generators, vacuum truck and dump trucks, semi-truck and flatbed trailer, various work trucks and fuel storage facilities. In the tunneling option, equipment would be located onshore. Typical tunneling operations include: tunnel boring machine, compressed air chamber and associated equipment, slurry pumps, slurry separation plant, ventilation fans, locomotive and mancars/segment cars/utility cars for inside tunnel hauling, crane, loader, forklift, boom truck, compressors, generators, grout plant, air plant, excavator, backhoe, dump truck, semi-truck and flatbed trailer, various work trucks and fuel storage facilities.

Fuel usage for the three trenchless options [3] is estimated as:

Fuel Usage (gal/day)

HDD	Microtunneling	Tunneling
400 to 600	200 to 300	400 to 500

In the tunneling option, because of the duration and because operations will occur onshore, a power drop from the utility company may provide power instead of using generators.

In all three options, it is anticipated that trucks will be needed to haul spoils (excavated materials from the drilling operations). Trucks will also be used to transport material and equipment to and from the designated work areas. Spoils will be hauled to the Waimanalo Gulch Landfill for disposal using large (18 wheeler) semi dump trucks. It is estimated that 7,170 cubic yards of excavated material will need to be disposed of [4]. Assuming 15 cubic yard capacity per truck, a total of about 478 truckloads would be required. About half of these would likely come from the Kaneohe WWPTF site and half from the H-3 Interchange site. The spoils will accumulate over time as construction proceeds and be stored onsite. At some point later in the construction schedule, it is anticipated that the spoils will be removed from the two sites over a two-week period. It is estimated that the spoils would be hauled out at a rate of up to six trucks per hour first from one site and then the other (but not both simultaneously). At the Kaneohe WWPTF site, haul trucks would traverse Kulauli Street and Puohala Street to Kaneohe Bay Drive and then follow Kaneohe Bay Drive to Likelike Highway to the H-3 Freeway to the H-1 Freeway and on to the Waimanalo Gulch Landfill. At the H-3 Interchange site, trucks would follow the H-3 Freeway to the H-1 Freeway and on to the landfill.

It is currently estimated that the period of construction would be three years. The first year would primarily be utilized for planning, mobilizing equipment and ordering construction materials. Following this, the active construction will likely occur over a two-year period.

Emission factors pertaining to diesel industrial engines are given in Table 5 both in terms of power output in units of pounds per horsepower-hour (lb/hp-hr) and fuel input in units of pounds per million Btu (lb/MMBtu). Using these emission factors and based on the estimated fuel usage noted above, and assuming the weight of diesel fuel is approximately 7 lbs per gallon and the heating value is approximately 19,300 Btu/lb, estimates of the resulting emissions from diesel fuel combustion can be obtained. These are indicated in Table 6. As shown in the table, nitrogen oxides emissions would be emitted at a rate of about 20 to 40 tons per year depending on the option selected for the trenchless construction. Smaller amounts of carbon monoxide, sulfur oxides, particulate matter and total organic compounds would be emitted. Microtunneling would likely yield the lowest emissions, although if power for the tunneling option is supplied by the utility, the estimated emissions would go down significantly.

Table 6 also includes an estimate of fugitive dust emissions. This is based on the EPA estimate [5] for uncontrolled fugitive dust emissions from construction activity of 1.2 tons per acre per month under conditions of "medium" activity, moderate soil silt content (30%), and precipitation/evaporation (P/E) index of 50. Uncontrolled fugitive dust emissions at the project site would likely be somewhere near that level, depending on the amount of rainfall that occurs. If it is assumed that an average of 10 acres will be involved in construction, uncontrolled fugitive dust emissions would amount to 144 tons per year.

The estimated emissions from spoils hauling are also indicated in Table 6. These pertain to the tailpipe emissions that would occur from trucks traveling from the project site to Waimanalo Gulch Landfill and return. Based on a roundtrip distance of approximately 70 miles and the required 478 trips, the total vehicle miles traveled would amount to 33,460. EPA emission factors for heavy-duty diesel vehicles [6] operating under average conditions were used to estimate the emission rates shown in the table. As shown in the table, emissions from spoils hauling will be relatively negligible.

One measure of the significance of the estimated project emissions is the "significant" emission rates defined by the Department of Health. Table 7 lists some of the relevant values. Based on the defined significant emission rates, the project emissions would be considered significant for particulate based on the fugitive dust emissions. The project could, perhaps, emit about 144 tons per year, and the defined significant emission rate is 25 tons per year. Other project emissions would not be considered significant, although nitrogen oxides emissions from diesel fuel use for horizontal directional drilling and for tunneling options are near the defined significant value.

Due to the prevailing onshore wind direction in the project area, project emissions will tend to be carried toward the populated areas of Kaneohe and Kailua.

Control of emissions from diesel fuel burning equipment at construction sites can most practically be accomplished by ensuring that engines are maintained properly and operating optimally. This will both save fuel and reduce emissions.

Adequate fugitive dust control can usually be accomplished by the establishment of a frequent watering program to keep bare-dirt surfaces in construction areas from becoming significant sources of dust. In dust-prone or dust-sensitive areas, other control measures such as limiting the area that can be disturbed at any given time, applying chemical soil stabilizers, mulching and/or using wind screens may be necessary. Control regulations further stipulate that open-bodied trucks be covered at all times when in motion if they are transporting materials that could be blown away. Haul trucks tracking dirt onto paved streets from unpaved areas is often a significant source of dust in construction areas. Some means to alleviate this problem, such as road cleaning or tire washing, may be appropriate. Monitoring dust at the project property line could be considered to quantify and document the effectiveness of dust control measures.

Project construction activities may also obstruct the normal flow of traffic at times to such an extent that overall vehicular emissions in the project area will temporarily increase. The only means to alleviate this problem will be to attempt to keep roadways open during peak traffic hours and to move heavy construction equipment and workers to and from construction areas during periods of low traffic volume.

7.0 CONCLUSIONS AND RECOMMENDATIONS

There is no specific air quality data available for the project area from the Department of Health, but based on measurements from leeward areas of Oahu and considering the windward location of the project, it is probable that existing air quality conditions are good and that all air quality standards are currently being met in the project area.

The fact that an alternative has been selected to route the proposed new force main under Kaneohe Bay, as opposed to routing it along existing roadways, is in and of itself, a major mitigation measure insofar as air quality is concerned. Nevertheless, for the alternative selected, there will be some unavoidable impacts on air quality in the project area during the period of construction. The major potential short-term air quality impact of the project will likely occur from the emission of fugitive dust. Dust emissions during construction can be controlled to some extent, but not eliminated. An effective dust control plan should be prepared and implemented to ensure that dust emissions are kept to a minimum.

Diesel fuel-burning equipment will also result in the emission of nitrogen oxides and carbon monoxide and to a lesser extent sulfur oxides, particulate, volatile organic compounds and other contaminants. These emission amounts should be relatively small and insignificant. Based on diesel fuel usage estimates, it is probable that the microtunneling option could have a slight advantage over other options for trenchless construction in that somewhat lower air pollution emissions would likely occur.

Any air pollution emissions that do occur at the shoreline or over Kaneohe Bay during project construction will tend to be carried toward populated areas by the prevailing onshore winds.

REFERENCES

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2. Austin, Tsutsumi & Associates, Inc., Design Alternatives Report for Kaneohe/Kailua Force Main No. 2, Project No. 2006051, January 29, 2010.

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5. Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, Fifth Edition, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1995.

6. User's Guide to MOBILE6.2, Mobile Source Emission Factor Model, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division, Ann Arbor, Michigan, January 2002.

Figure 1 - Location Map

Table 1

SUMMARY OF STATE OF HAWAII AND NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Units	Averaging Time	Maximum Allowable Concentration		
			National Primary	National Secondary	State of Hawaii
Particulate Matter (<10 microns)	$\mu g/m^3$	Annual	–	–	50
		24 Hours	150[a]	150[a]	150[b]
Particulate Matter (<2.5 microns)	$\mu g/m^3$	Annual	15[c]	15[c]	–
		24 Hours	35[d]	35[d]	–
Sulfur Dioxide	$\mu g/m^3$	Annual	80	–	80
		24 Hours	365[b]	–	365[b]
		3 Hours	–	1300[b]	1300[b]
Nitrogen Dioxide	$\mu g/m^3$	Annual	100	100	70
		1 Hour	189[d]	–	–
Carbon Monoxide	mg/m^3	8 Hours	10[b]	–	5[b]
		1 Hour	40[b]	–	10[b]
Ozone	$\mu g/m^3$	8 Hours	157[e]	157[e]	157[e]
		1 Hour	235[f]	235[f]	–
Lead	$\mu g/m^3$	3 Months	0.15[g]	0.15[g]	–
		Quarter	1.5[h]	1.5[h]	1.5[h]
Hydrogen Sulfide	$\mu g/m^3$	1 Hour	–	–	35[b]

[a] Not to be exceeded more than once per year on average over three years.
[b] Not to be exceeded more than once per year.
[c] Three-year average of the weighted annual arithmetic mean.
[d] 98th percentile value averaged over three years.
[e] Three-year average of fourth-highest daily 8-hour maximum.
[f] Standard is attained when the expected number of exceedances is less than or equal to 1.
[g] Rolling 3-month average.
[h] Quarterly average.

Table 2

MEAN WIND SPEED AND PREVAILING DIRECTION FOR KANEOHE MARINE CORPS AIR STATION, OAHU, HAWAII

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Speed (mph)	7.4	8.4	8.4	9.4	8.1	9.3	9.7	8.7	8.2	8.0	7.7	7.8	8.4
Direction	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	E	ENE

Period of Record: 1996 - 2006

Source: Desert Research Institute, Western Regional Climate Data Center, Reno, Nevada

Table 3

AIR POLLUTION EMISSIONS INVENTORY FOR ISLAND OF OAHU, 1993

Air Pollutant	Point Sources (tons/year)	Area Sources (tons/year)	Total (tons/year)
Particulate	25,891	49,374	75,265
Sulfur Oxides	39,230	nil	39,230
Nitrogen Oxides	92,436	31,141	123,577
Carbon Monoxide	28,757	121,802	150,559
Hydrocarbons	4,160	421	4,581

Source: Final Report, "Review, Revise and Update of the Hawaii Emissions Inventory Systems for the State of Hawaii", prepared for Hawaii Department of Health by J.L. Shoemaker & Associates, Inc., 1996

Table 4

ANNUAL SUMMARIES OF AIR QUALITY MEASUREMENTS FOR SELECTED MONITORING STATIONS ON OAHU

Parameter / Location	2004	2005	2006	2007	2008
Sulfur Dioxide / Honolulu					
3-Hour Averaging Period:					
No. of Samples	2889	1483	1138	2827	2876
Highest Concentration ($\mu g/m^3$)	56	75	43	55	29
2nd Highest Concentration ($\mu g/m^3$)	46	57	36	47	29
No. of State AAQS Exceedances	0	0	0	0	0
24-Hour Averaging Period:					
No. of Samples	364	187	146	359	363
Highest Concentration ($\mu g/m^3$)	25	23	13	18	10
2nd Highest Concentration ($\mu g/m^3$)	13	18	5	13	10
No. of State AAQS Exceedances	0	0	0	0	0
Annual Average Concentration ($\mu g/m^3$)	1	1	1	3	3
Particulate (PM-10) / Honolulu					
24-Hour Averaging Period:					
No. of Samples	342	173	141	344	343
Highest Concentration ($\mu g/m^3$)	39	64	25	33	33
2nd Highest Concentration ($\mu g/m^3$)	35	28	23	29	31
No. of State AAQS Exceedances	0	0	0	0	0
Annual Average Concentration ($\mu g/m^3$)	13	15	13	14	14
Carbon Monoxide / Honolulu					
1-Hour Averaging Period:					
No. of Samples	8673	4197	3612	8627	8732
Highest Concentration (mg/m^3)	2.7	3.9	2.8	2.3	2.4
2nd Highest Concentration (mg/m^3)	2.7	3.1	1.9	1.8	2.1
No. of State AAQS Exceedances	0	0	0	0	0
8-Hour Averaging Period:					
No. of Samples	8684	4180	3610	8635	8735
Highest Concentration (mg/m^3)	1.5	1.6	1.2	1.3	1.2
2nd Highest Concentration (mg/m^3)	1.5	1.6	1.2	1.2	1.2
No. of State AAQS Exceedances	0	0	0	0	0
Nitrogen Dioxide / Kapolei					
Annual Average Concentration ($\mu g/m^3$)	9	9	9	9	8
Ozone / Sand Island					
8-Hour Averaging Period:					
No. of Samples	8474	8670	8591	357	305
Highest Concentration (mg/m^3)	110	92	83	71	98
2nd Highest Concentration (mg/m^3)	108	92	83	69	94
No. of State AAQS Exceedances	0	0	0	0	0

Source: State of Hawaii Department of Health, "Annual Summaries, Hawaii Air Quality Data, 2004 - 2008"

Table 5

AIR POLLUTION EMISSION FACTORS FOR UNCONTROLLED DIESEL INDUSTRIAL ENGINES[a]

Air Pollutant	Emission Factor (lb/hp-hr) (power output)	Emission Factor (lb/MMBtu) (fuel input)
Nitrogen Oxides	0.0310	4.41
Carbon Monoxide	0.0067	0.95
Sulfur Oxides	0.0020	0.29
Particulate	0.0022	0.31
Total Organic Compounds	0.0025	0.35

[a]Based on U.S. EPA emission factors for uncontrolled gasoline and diesel industrial engines [5].

Table 6

ORDER OF MAGNITUDE ESTIMATED AIR POLLUTION EMISSIONS DURING CONSTRUCTION AT KANEOHE/KAILUA FORCE MAIN NO. 2 PROJECT

Source	Air Pollution Emissions (tons per year)				
	Nitrogen Oxides	Carbon Monoxide	Sulfur Oxides	Particulate Matter	Total Organic Compounds
Diesel Fuel Usage:					
Horizontal Direct Drilling	39	8	2	3	3
Microtunneling	20	4	1	2	2
Tunneling	35	7	2	2	3
Fugitive Dust[a]	–	–	–	144	–
Spoils Hauling	0.05	0.4	–	–	0.08

[a]Assumes an average active construction area of 10 acres.

Table 7

SIGNIFICANT AIR POLLUTION EMISSION RATES[a]

Air Pollutant	Significant Emission Rate (tons per year)
Nitrogen Oxides	40
Carbon Monoxide	100
Sulfur Oxides	40
Particulate	25
Total Organic Compounds	40

[a]Hawaii Administrative Rules, Title 11, Chapter 60.1

Appendix K

Update of Noise Impact Assessments for the Kaneohe / Kailua Force Main No. 2 Alternative Under Kaneohe Bay
Y. Ebisu & Associates
December 2010

Acoustic Study for the Kaneohe / Kailua Force Main No. 2 Trenchless Options Under Kaneohe Bay
Y. Ebisu & Associates
March 2010

Y. Ebisu & Associates
Acoustical and Electronic Engineers

1126 12th Ave., Room 305
Honolulu, Hawaii 96816
Ph. (808) 735-1634 – Fax (808) 732-0409
e-mail: ebisuyassoc@aol.com

YEA Job #47.052
December 6, 2010

Austin, Tsutsumi & Associates, Inc.
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817

Attention: Mr. Ivan K. Nakatsuka, P.E.

Subject: Update Of Noise Impact Assessments for the Kaneohe / Kailua Force Main No. 2 Alternative Under Kaneohe Bay

Dear Mr. Nakatsuka:

Background: In March 2010, a noise impact assessment report was provided which evaluated the potential noise impacts associated with seven (7) trenchless options for construction of the subject force main under Kaneohe Bay (Y. Ebisu & Associates; Acoustic Study for the Kaneohe / Kailua Force Main No. 2 Trenchless Options Under Kaneohe Bay; March 2010). Following completion of the March 2010 report, the number of options for the force main construction was reduced from seven to two. This letter report provides additional information about the remaining two options, which are similar to Option 1 and Option 4 described in the March 2010 report. Evaluations of potential noise and vibration impacts from pile driving activities near the underwater entry and exit points at the ends of the underwater sections of the force main were not included in the March 2010 report, and have been included in this letter report.

Description of Potential Noise Levels During Option 1 Construction. Force Main Option 1 involves the construction of the underwater section of the force main along an alignment shown in Figure 1A. This alignment is similar to that shown in the March 2010 report for Options 1 through 4. Horizontal Directional Drilling (HDD) rigs will probably be located at the Kaneohe Wastewater Pump Station (WWPS) and Kailua Wastewater Treatment Plant (WWTP) ends of the underwater force main section. Sheet pile driving will probably be required at both ends during open trenching and pit excavation activities, and vertical pile driving will also be required to anchor the HDD rig at each end of the under bay force main. In addition, the use of a small diameter casing (or conductor barrel) during the pilot hole drilling at the Kaneohe WWPS end will be required to prevent mud return during the pilot hole drilling. This casing will need to be driven into the ground along the slanted drill path using a hydraulic or air driven hammer.

The predicted noise levels at the closest residences to the construction sites at both the Kaneohe WWPS and Kailua WWTP ends of the Option 1 alignment are shown in Table 5A. Construction noise levels will be highest (73 to 79 dBA) at residences across Kaneohe Stream toward Heeia due to the relatively small (150 to 250 feet) buffer distances between the residences and the construction equipment. Residences which are west of the Kailua WWTP end of the under bay force main section will experience the next highest construction noise levels of 65 to 66 dBA, followed by Aikahi Gardens residences with construction noise levels of 59 to 60 dBA. Residences to the south of the Kaneohe WWPS end of the under bay force main section are predicted to experience the lowest construction noise levels of 55 to 58 dBA. During impact pile driving activities at the Kaneohe WWPS end, maximum noise levels associated with the pile driver impacts are predicted to be 8 to 11 dBA higher than during the other construction activities.

Description of Potential Noise Levels During Option 2 Construction. Force Main Option 2 involves the construction of the underwater section of the force main along an alignment shown in Figure 1A. This alignment is similar to that shown in the March 2010 report for Options 1 through 4. Option 2 will involve the use of Hybrid Tunneling (Microtunneling for the first 3,000 feet using jacked steel casing, followed by the same Tunnel Boring Machine (TBM) system equipped to continue with the installation of concrete segmental liners for the remainder of the tunnel to the Kailua WWTP receiving pit. Essentially all of the construction work for Hybrid Tunneling will occur at the Kaneohe WWPS jacking/launching pit, with the construction work on the Kailua WWTP side primarily involving the construction of the TBM recovery pit and recovery of the TBM.

The predicted noise levels at the closest residences to the construction sites at both the Kaneohe WWPS and Kailua WWTP ends of the Option 2 alignment are shown in Table 5A. Construction noise levels will be highest (70 to 79 dBA) at residences across Kaneohe Stream toward Heeia due to the relatively small buffer distances between the residences and the construction equipment. Residences which are west of the Kailua WWTP end of the under bay force main section will experience the next highest construction noise levels of approximately 68 dBA, followed by Aikahi Gardens residences with construction noise levels of approximately 62 dBA. Residences to the south of the Kaneohe WWPS end of the under bay force main section are predicted to experience the lowest construction noise levels of 55 to 58 dBA. The noise from impact pile driving activities will be associated with the installation of shoring plates during trenching and pit construction at both ends of the under bay force main section.

Potential Noise and Vibration Impacts During Construction Under Option 1. Audible construction noise will probably be unavoidable during the entire project construction period. The total time period for actual construction is estimated to be approximately two years, with most of the noisier work being performed during the normally permitted hours of 7:00 am to 6:00 pm on weekdays, and between 9:00 am to 6:00 pm on Saturdays. Actual length of exposure to construction noise at any receptor location will probably be less than the total construction period for the entire project. Typical levels of exterior noise from construction activity at the closest residential receptors for the under bay construction Options 1 and 2 were described previously and are summarized in Table 5A and Figure 5 (from the March 2010 noise study report). Construction noise levels will be audible at the closest residences, and will exceed existing daytime background noise levels by 10 to 25 dBA. At the closest residences to the Kaneohe WWPS end of the under bay force main, the maximum impulsive noise during pile driving activities will be approximately 11 dBA higher than from the other fixed and mobile construction equipment. Typical levels of construction noise inside naturally ventilated and air conditioned structures are approximately 10 and 20 dBA less, respectively, than the levels shown in Table 5A and Figure 5.

Pile driving will probably be necessary to implant sheet or vertical pipe piles and the slanted pipe casing into the ground at the project work sites. While vibrator type pile drivers may also be used, the use of impact driven piles, pipes, and casings was assumed for the noise and vibration level estimates. Induced ground vibrations from the pile driving operations have the potential to cause architectural and structural damage to structures.

Ground vibrations generated during pile driving operations are generally described in terms of peak particle (or ground) velocity in units of inches/second. The human being is very sensitive to ground vibrations, which are perceptible at relatively low particle velocities of 0.01 to 0.04 inches/second. Damage to structures, however, occur at much higher levels of vibration as indicated in Table 6. The most commonly used damage criteria for structures is the 2.0 inches/second limit derived from work by the U.S. Bureau of Mines. A more conservative limit of 0.2 inches/second is also used, and is suggested for planning purposes on this project because of the repetitive nature of pile driving operations which can increase risks of damage due to fatiguing.

Based on measured vibration levels during pile driving operations under various soil conditions and at various distances, estimates of ground vibration levels vs. distance from the pile driver have been made for various soil conditions and for various energy ratings of the pile drivers. Figure 7, which was extracted from "Damage of Pile Driving Vibration," Highway Research Record, Number 155, may be used to predict vibration levels for the soil conditions indicated. When coral layers must be penetrated, vibration levels can be expected to be higher than those shown in Figure 7, particularly if the adjacent structures are supported by the common coral layer. From Figure 7, and for wet sand soil conditions, the 0.2 inches/second vibration damage criteria will be exceeded at a scaled energy distance factor of approximately 0.7. The scaled energy distance factor is equal to the square root of the energy (in foot-pounds) per blow of the hammer divided by the distance (in feet) between the pile tip and the monitoring location. For a 2,500 foot-pound small pile driver, a scaled energy distance of 0.7 equates to a required separation distance of 71 feet. Under clay soil conditions, and using the prediction procedures contained in Figure 7, a shorter separation distance of 47 feet is required to not exceed the 0.2 inches/second criteria when using a 2,500 foot-pound pile driver. It should be noted that 0.2 inches/second vibration levels were measured from a much larger 22,400 foot-pound pile driver at even shorter separation distances of approximately 30 feet in sandy, layered soil ("Some Aspects of the Ground Vibration Problem," Noise Control Engineering, May-June 1978). The measurement data reported in the Noise Control Engineering paper are significantly lower than the vibration levels predicted by the methodology of Figure 7.

Because the separation distances between the pile drivers and the closest residences are much larger than 71 feet, risks of architectural or structural damage from pile driving using a 2,500 foot-pound small pile driver are considered to be very low. Using the more conservative methodology of Figure 7, it is possible that ground vibrations may be perceptible (at approximately 0.01 inches per second) out to distances of approximately 500 feet from a 2,500 foot-pound small pile driver. However, risks of adverse impacts from vibrations at these levels are considered to be low as long as pile driving activities occur only during the daytime hours normally permitted by the State Department of Health (DOH) for pile driving activities.

Potential Noise and Vibration Impacts During Construction Under Option 2. Potential noise and vibration impacts during construction under Option 2 at the Kaneohe WWPS end of the under bay force main are expected to be similar to those described under Option 1, except that the use of vertical and inclined pile driving for anchor pipes and casings should not be required under Option 2. Actual length of the construction period may be at least 3 years instead of the 2 years for Option 1. At the Kailua WWTP end of the under bay force main, the TBM recovery pit will be closer to Aikahi Gardens residences. However construction activities under Option 2 will occur primarily in conjunction with construction of the TBM recovery pit and TBM recovery operations after the Hybrid Tunnel has been completed. Under Option 2, highest construction noise levels are predicted at the residences closest to the launching pit at the Kaneohe WWPS end of the under bay force main. Therefore, under either Option 1 or Option 2, the Kaneohe residences located on the Heeia side of the force main alignment are expected to experience the highest noise levels during project construction.

Noise from Heavy Trucks During Spoils Transporting Operations. Under both Options 1 and 2, the maximum number of heavy truck trips in and out of the Kaneohe or Kailua work sites should range from 2 to 5 trips per hour (over a 10 hour hauling period). Materials excavated from under Kaneohe Bay will be collected at the Kaneohe end and possibly at the H-3 Interchange end of the selected under bay force main alignment. These materials (or spoils) will need to be transported to a landfill site in Waianae or other locations on Oahui using dump trucks at a maximum frequency of 6 loads per hour from each of the two ends of the under bay force main alignment.

The maximum noise level during the truck passby may be as high as 90 dBA at 50 feet and 94 dBA at 25 feet distance from the roadway centerline. At a total of 6 (3 inbound plus 3 outbound) heavy truck trips per hour, the average hourly noise level from the truck trips could be as high as 60 Leq(h) at 50 feet, and 64 Leq(h) at 25 feet from the roadway centerline. Assuming that this rate of heavy truck traffic is maintained for 10 hours per day, the average DNL value of the truck noise is predicted to range between 56 DNL at 50 feet to 60 DNL at 25 feet from the roadway centerline.

The heavy truck route between Kaneohe Bay Drive and the Kaneohe WWPS may be along Puohala and Kulauli Streets, which passes through residential areas. This situation is considered to have the worst case potential for adverse noise impacts from heavy truck traffic due to the relatively short setback distances to the residences and because of the relatively lower levels of existing traffic and background noise along these two streets. The typical setback distances from the centerlines of these streets to the residences range from approximately 35 to 55 feet. Therefore, predicted noise levels during a 10 hour materials hauling day from the heavy truck traffic could range from 60 to 62 DNL. These levels are below the FHA/HUD noise standard of 65 DNL for residences, and should be below the federally accepted threshold for adverse noise impact.

At the Kailua WWTP end of the under bay force main work site, a maximum of 3 heavy truck trips per hour is anticipated in and out of the work site over a 10 hour hauling period. The average hourly noise level from the truck trips could be as high as 58 Leq(h) at 50 feet, and 62 Leq(h) at 25 feet from the roadway centerline. Assuming that this rate of heavy truck traffic is maintained for 10 hours per day, the average DNL value of the truck noise is predicted to range between 54 DNL at 50 feet to 58 DNL at 25 feet from the roadway centerline. These levels of heavy truck traffic noise are well below the existing traffic noise levels along Kaneohe Bay Drive and Mokapu Boulevard (in excess of 60 Leq(h) and 60 DNL at 50 feet setback distances from their centerlines).

Possible Noise Mitigation Measures. Mitigation of construction noise to inaudible levels will not be practical in all cases due to the intensity of construction noise sources

(80 to 90+ dBA at 50 FT distance), and due to the exterior nature of the work (excavating, pile driving, grading and earth and spoils moving, trenching, crane operations, hammering, etc.). The use of properly muffled construction equipment should be required on the job site. The anticipated noise levels during actual construction activities are typical of other construction activities (exterior earthwork, open trenching, or building erection).

Noise mitigation measures should be included in the Force Main No. 2 project if the under bay trenchless construction alternative is selected. The following noise mitigation measures are recommended for inclusion within the project construction documents:

1. Provide sound attenuation treatments to reduce all steady, continuous noise sources (generators, pumps, plants, fans, etc.) which operate during the normally permitted daytime hours so that they do not exceed 65 dBA at the closest residences. In order to achieve this, the addition of sound attenuating barriers or equipment enclosures will probably need to be included in the project. If it is tall enough, a sound attenuating wall can provide approximately 20 dBA of sound attenuation. As indicated in TABLE 5A, a maximum of 34 dBA of sound attenuation could be required to meet the 45 dBA DOH nighttime requirement at the residences on the Heeia side of the Kaneohe WWPS work areas. Therefore, the use of quieted equipment or large area enclosures may be required if continuous work is required during the nighttime period.

2. Select the under bay option which requires the least amount of construction during the nighttime or weekend periods, and which would require the issuance of a noise variance by the State DOH. Alternately, require that fixed machinery used in nighttime or weekend work during the noise variance periods do not exceed 45 dBA at the closest residences.

3. Require the installation and use of broadband back-up alarms in place of beeper-type back-up alarms for all mobile equipment operating on the project work sites. The broadband alarms should be less audible at the longer distances, and should be less annoying at all distances from the mobile construction equipment. Use broadband alarms which automatically adjust the alarm sound level for differences in background noise level.

4. If prolonged periods of work are required during the non-permitted (or noise variance) hours, consider the use of HECO electrical service drops at the two ends of the under bay force main in place of portable generators and engine driven equipment (pumps, lights, etc.). These service drops may also be used to meet the 65 dBA maximum daytime level recommendation in Paragraph 1, and the 45 dBA nighttime level recommendation in Paragraph 2.

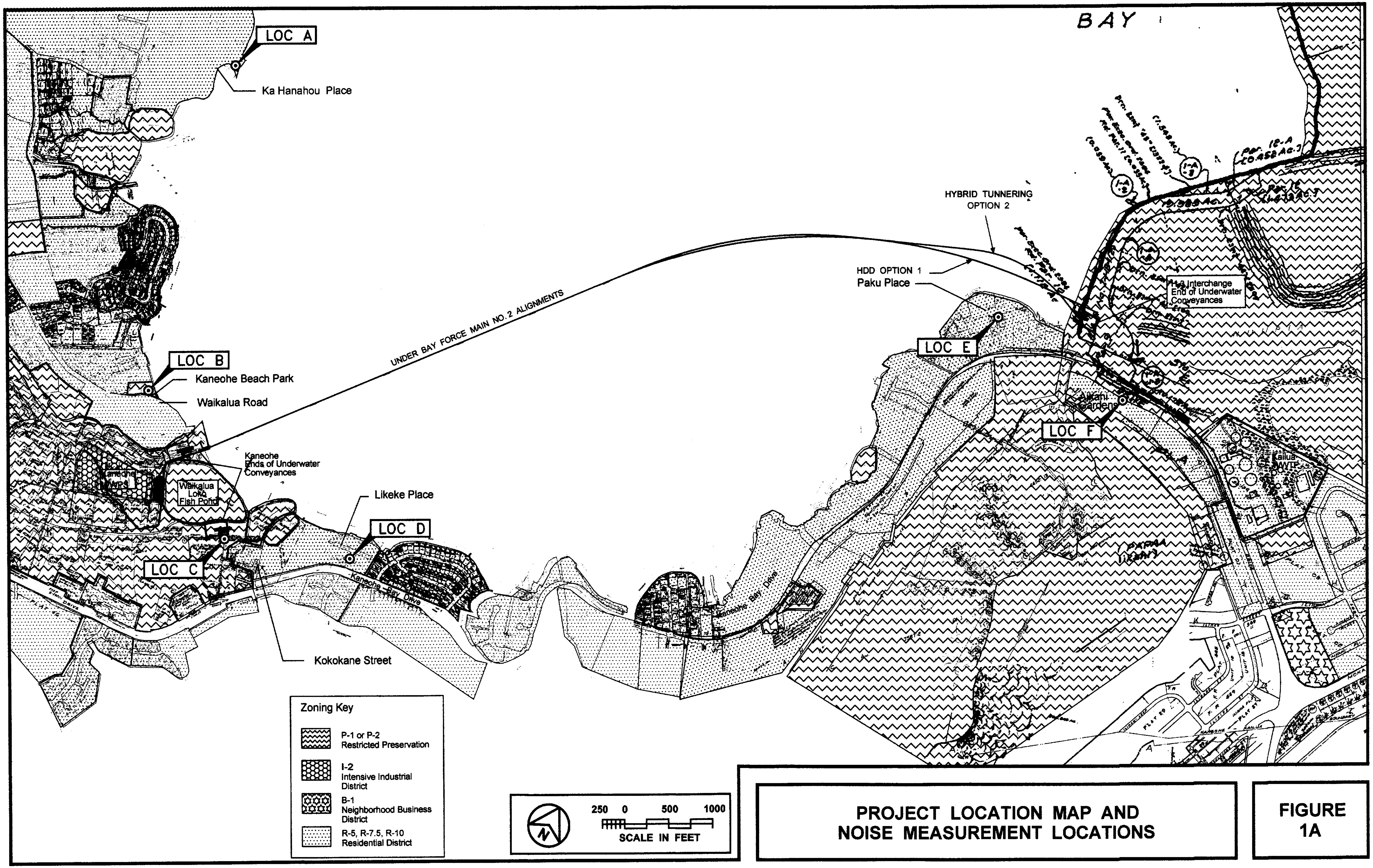
5. Investigate the feasibility of adding an alternate truck route between Kaneohe Bay Drive and the Kaneohe WWPS construction site for spoils removal.

6. Notify nearby residents prior to commencing excessively noisy construction activities so that they have an opportunity to schedule their activities to avoid adverse noise impacts from construction activities. Also, maintain a complaint phone line that is continuously manned during periods of construction at both the Kaneohe WWPS and Kailua WWTP work sites.

Sincerely,

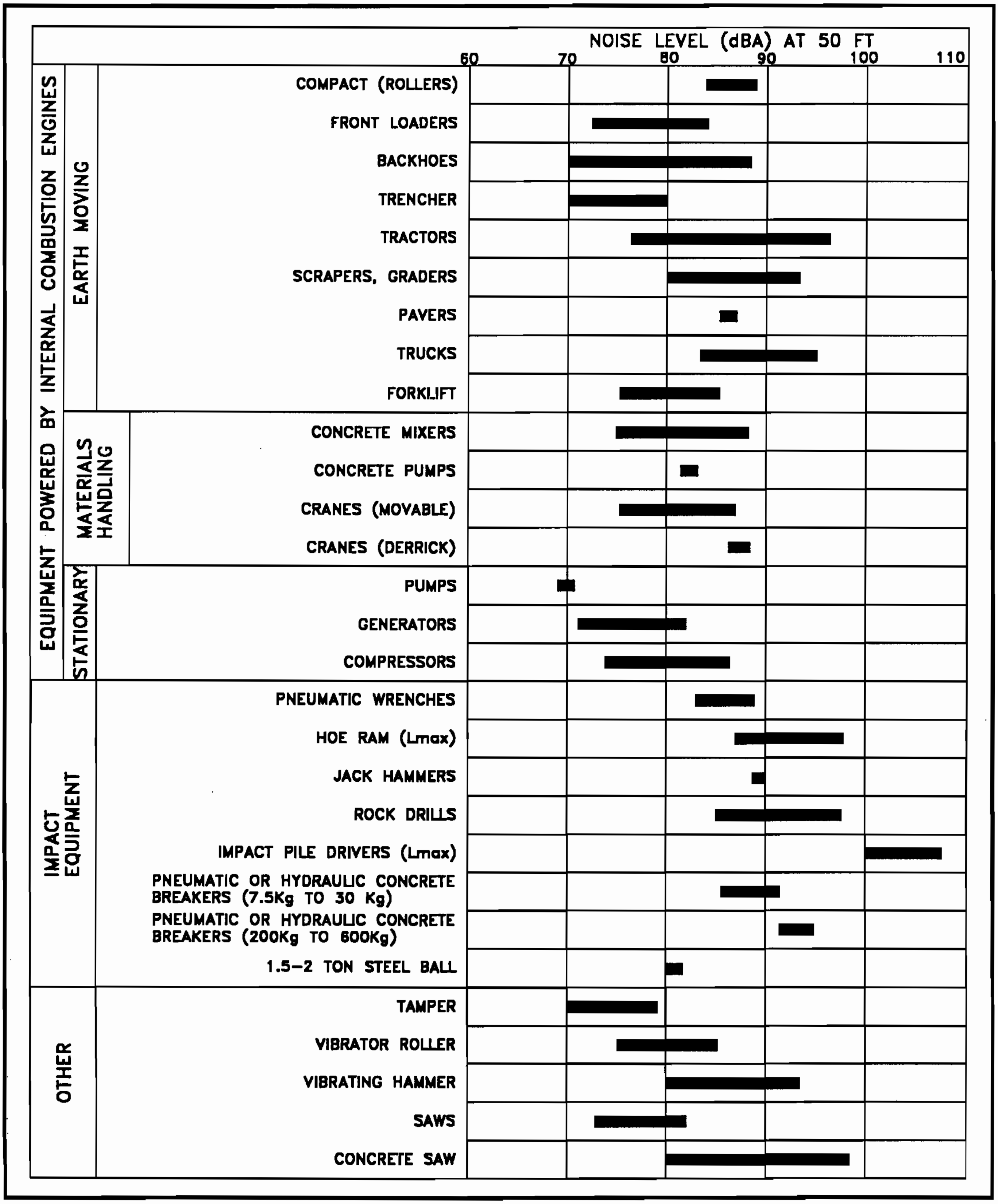
Yoichi Ebisu, P.E.

encl.



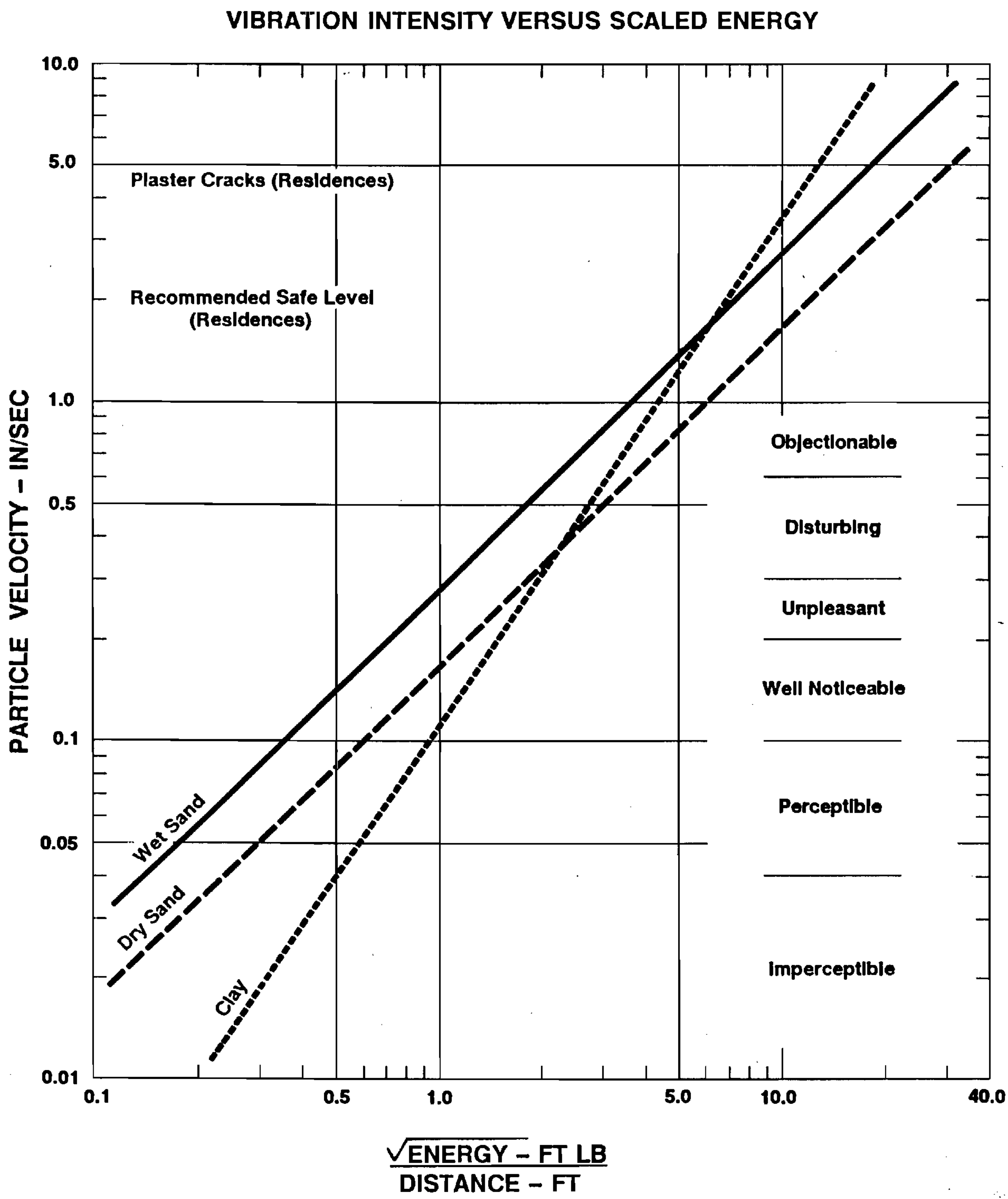
PROJECT LOCATION MAP AND NOISE MEASUREMENT LOCATIONS

FIGURE 1A



RANGES OF CONSTRUCTION EQUIPMENT NOISE LEVELS

FIGURE 5



MINIMUM VIBRATION INTENSITIES EXPECTED FROM PILE DRIVING

FIGURE 7

TABLE 5A
SUMMARY OF UNDERBAY HDD AND HYBRID TUNNEL OPTIONS

	************************************** CONSTRUCTION OPERATIONS AND PREDICTED NOISE LEVELS **		
OPTION	KANEOHE / BAY VIEW END	H-3 INTERCHANGE END	OVER WATER BARGES
HDD	HDD Rig; Cranes during pullback. 73 to 79 dBA @ Heeia Side 55 to 58 dBA @ K-Bay Drive Side	HDD Rig; Cranes during pullback. 65 to 66 dBA @ K-Bay Drive to Southwest 59 to 60 dBA @ Aikahi Gardens to Southeast	None.
HDD	Impact Pile Driving: 85 to 90 dBA @ Heeia Side 65 to 67 dBA @ K-Bay Drive Side	Impact Pile Driving: 74 to 76 dBA @ K-Bay Drive to Southwest 66 to 68 dBA @ Aikahi Gardens to Southeast	None
HYBRID TUNNEL	Tunnel Boring Machine 70 to 79 dBA @ Heeia Side 55 to 58 dBA @ K-Bay Drive Side	TBM Recovery 68 dBA @ K-Bay Drive to Southwest 62 dBA @ Aikahi Gardens to Southeast	None
HYBRID TUNNEL	Impact Pile Driving: 85 to 90 dBA @ Heeia Side 65 to 67 dBA @ K-Bay Drive Side	Impact Pile Driving: 76 to 78 dBA @ K-Bay Drive to Southwest 70 to 72 dBA @ Aikahi Gardens to Southeast	None
All	Open trenching from shore to Kaneohe WWPS.	Open trenching from H-3 to Kailua WWTP.	

Notes:
1. Typically, lower noise level is steady source level, and higher noise level is due to intermittent source.
2. Exception occurs when only intermittent sources operate.

TABLE 6

SUMMARY OF BUILDING DAMAGE CRITERIA

PEAK GROUND VELOCITY (mm/sec)	PEAK GROUND VELOCITY (in/sec)	COMMENT
193.04	7.6	Major damage to buildings (mean of data).
137.72	5.4	Minor damage to buildings (mean of data).
101.16	4.0	'Engineer structures' safe from damage.
50.8	2.0	Safe from damage limit (probability of damage <5%).
		No structural damage.
33.02	1.3	Threshold of risk of 'architectural' damage for houses.
25.4	1.0	No data showing damage to structures for vibration <1 in./sec.
15.24	0.6	No risk of 'architectural' damage to normal buildings.
10.16	0.4	Threshold of damage in older homes.
5.08	0.2	Statistically significant percentage of structures may experience minor damage (including earthquake, nuclear event, and blast data for old and new structures).
		No 'architectural' damage.
3.81	0.5 to 0.15	Upper limits for ruins and ancient monuments.
1.0	0.04	Vertical vibration clearly perceptible to humans.
0.32	0.01	Vertical vibration just perceptible to humans.

Source: 'State-of-the-Art Review: Prediction and Control of Groundborne Noise and Vibration from Rail Transit Trains'; U.S. Department of Transportation; December 1983.

ACOUSTIC STUDY FOR THE KANEOHE / KAILUA FORCE MAIN NO. 2 TRENCHLESS OPTIONS UNDER KANEOHE BAY

Prepared for:

AUSTIN, TSUTSUMI & ASSOCIATES, INC.

Prepared by:

Y. EBISU & ASSOCIATES
1126 12th Avenue, Room 305
Honolulu, Hawaii 96816

MARCH 2010

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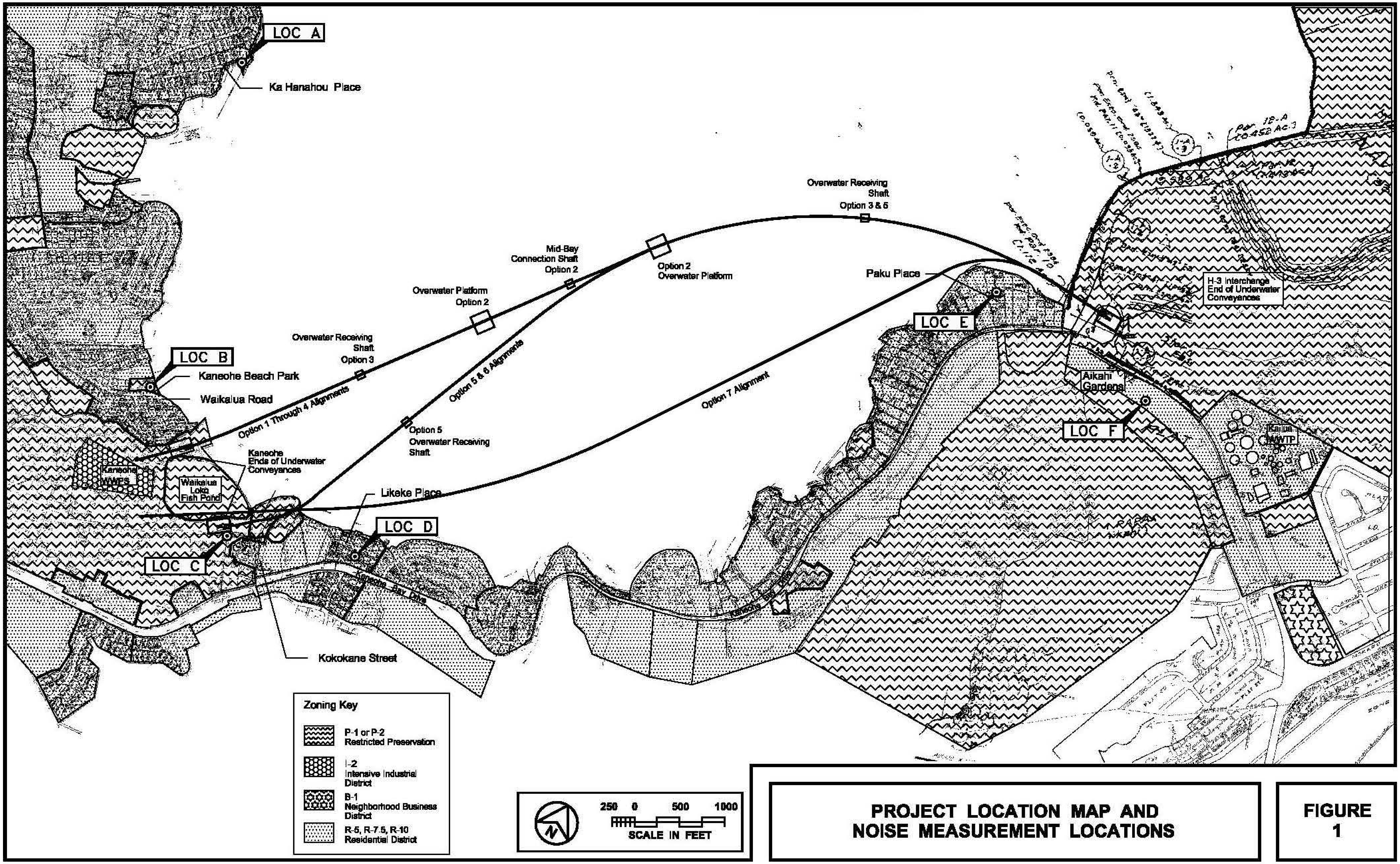
CHAPTER I. SUMMARY

The existing and potential construction noise levels in the vicinity of the Kaneohe / Kailua Force Main No. 2 alignments under Kaneohe Bay were evaluated for their potential impacts and their relationship to the current FHA/HUD noise standard. The potential construction noise levels associated with seven underbay force main construction alternatives using trenchless construction methods (see FIGURE 1) were evaluated. In addition, the potential construction noise levels and impacts associated with required open trenching operations and the transportation of spoils and materials from the construction sites were evaluated.

The potential noise impacts during trenchless construction of the Kaneohe / Kailua Force Main No. 2 are more dependent on where the staging areas are located at the Kaneohe end of the force main alignment, rather than on the type of trenchless method used for the construction of the force main. That is because they all typically utilize diesel engine powered equipment, both fixed and mobile. The highest construction noise levels and potential noise impacts are associated with the construction site (Underbay Options 1 through 4) located on the finger of land on the Heeia side of the Waikalua Loko Fishpond, which is approximately 200 feet from the closest residences across the drainage canal and along Holowai Street. The lowest construction noise levels and potential noise impacts are associated with the Tunnel Boring Machine site (Underbay Option 7) next to the Kaneohe WWPS, which is at least 700 feet from the closest residence.

As is the situation with all large construction projects, it will not be practical to reduce construction noise to inaudible levels. It will not be feasible to eliminate all noise impacts during construction of the project. But because of the relatively long period of actual construction activities and the relatively low levels of background noise in the surrounding area, special construction noise mitigation measures are recommended. These measures include: sound attenuation treatment of fixed machinery which operate continuously so as to limit their combined maximum noise levels to 65 dBA at the closest residences; selection of the underbay construction alternative which minimizes the required time of construction during the nighttime and weekend periods (which require the issuance of a noise variance; requiring the use of broadband back-up alarms for vehicles which operate on the construction sites in place of the more commonly used high frequency, beeper back-up alarms; consideration of the use of HECO service drops if necessary to meet the project noise limits during the daytime or nighttime periods; and investigation of the feasibility of using an alternate heavy truck route for transporting spoils and materials to and from the Kaneohe WWPS construction site.



PROJECT LOCATION MAP AND NOISE MEASUREMENT LOCATIONS

FIGURE 1

CHAPTER II. PURPOSE

The primary objective of this study was to describe the existing and potential noise environment in the environs of the proposed Kaneohe / Kailua Force Main No. 2 project on the windward side of the island of Oahu. This study was limited to noise impacts during construction. The potential noise impacts were examined for the options involving construction of Force Main No. 2 using trenchless methods with alignments under Kaneohe Bay. A specific objective was to estimate potential construction equipment noise levels associated with the construction of Force Main No. 2 under Kaneohe Bay, and to describe the potential noise impacts in the residential areas in the immediate vicinity of the project.

Recommendations for minimizing potential construction noise impacts were also to be provided as required.

CHAPTER III. NOISE DESCRIPTORS AND THEIR RELATIONSHIP TO LAND USE COMPATIBILITY

The noise descriptor currently used by federal agencies (such as FHA/HUD) to assess environmental noise is the Day-Night Average Sound Level (DNL). This descriptor incorporates a 24-hour average of instantaneous A-Weighted Sound Levels as read on a standard Sound Level Meter. By definition, the minimum averaging period for the DNL descriptor is 24 hours. Additionally, sound levels which occur during the nighttime hours of 10:00 PM to 7:00 AM are increased by 10 decibels (dB) prior to computing the 24-hour average by the DNL descriptor. A more complete list of noise descriptors is provided in APPENDIX B to this report.

TABLE 1, derived from Reference 1, presents current federal noise standards and acceptability criteria for residential land uses. TABLE 2, also extracted from Reference 1, presents the general effects of noise on people in residential use situations. Land use compatibility guidelines for various levels of environmental noise as measured by the DNL descriptor system are shown in FIGURE 2 (from Reference 2). As a general rule, noise levels of 55 DNL or less occur in rural areas, or in areas which are removed from high volume roadways. In urbanized areas which are shielded from high volume streets, DNL levels generally range from 55 to 65 DNL, and are usually controlled by motor vehicle traffic noise. Residences which front major roadways are generally exposed to levels of 65 DNL, and as high as 75 DNL when the roadway is a high speed freeway. In the project area immediately adjacent to Kaneohe Bay, traffic noise levels (as well as background noise levels) tend to be very low, and are at or less than 55 DNL.

For purposes of determining noise acceptability for funding assistance from federal agencies (FHA/HUD and VA), an exterior noise level of 65 DNL or less is considered acceptable for residences. This standard is applied nationally (Reference 3), including Hawaii. Because of our open-living conditions, the predominant use of naturally ventilated dwellings, and the relatively low exterior-to-interior sound attenuation afforded by these naturally ventilated structures, an exterior noise level of 65 DNL does not eliminate all risks of noise impacts. Because of these factors, and as recommended in Reference 4, a lower level of 55 DNL is considered as the "Unconditionally Acceptable" (or "Near-Zero Risk") level of exterior noise. However, after considering the cost and feasibility of applying the lower level of 55 DNL, government agencies such as FHA/HUD and VA have selected 65 DNL as a more appropriate regulatory standard.

For commercial, industrial, and other non-noise sensitive land uses, exterior noise levels as high as 75 DNL are generally considered acceptable. Exceptions to this occur when naturally ventilated office and other commercial establishments are exposed to exterior levels which exceed 65 DNL.

On the island of Oahu, the State Department of Health (DOH) regulates noise from construction activities through the issuance of permits for allowing excessive

TABLE 1

EXTERIOR NOISE EXPOSURE CLASSIFICATION (RESIDENTIAL LAND USE)

NOISE EXPOSURE CLASS	DAY-NIGHT SOUND LEVEL	EQUIVALENT SOUND LEVEL	FEDERAL (1) STANDARD
Minimal Exposure	Not Exceeding 55 DNL	Not Exceeding 55 Leq	Unconditionally Acceptable
Moderate Exposure	Above 55 DNL But Not Above 65 DNL	Above 55 Leq But Not Above 65 Leq	Acceptable(2)
Significant Exposure	Above 65 DNL But Not Above 75 DNL	Above 65 Leq But Not Above 75 Leq	Normally Unacceptable
Severe Exposure	Above 75 DNL	Above 75 Leq	Unacceptable

Notes: (1) Federal Housing Administration, Veterans Administration, Department of Defense, and Department of Transportation.

(2) FHWA uses the Leq instead of the Ldn descriptor. For planning purposes, both are equivalent if: (a) heavy trucks do not exceed 10 percent of total traffic flow in vehicles per 24 hours, and (b) traffic between 10:00 PM and 7:00 AM does not exceed 15 percent of average daily traffic flow in vehicles per 24 hours. The noise mitigation threshold used by FHWA for residences is 67 Leq.

TABLE 2

EFFECTS OF NOISE ON PEOPLE
(Residential Land Uses Only)

EFFECTS[1] / DAY-NIGHT AVERAGE SOUND LEVEL IN DECIBELS	Hearing Loss	Speech Interference		Annoyance[2]	Average Community Reaction[4]	General Community Attitude Towards Area
		Indoor	Outdoor			
	Qualitative Description	%Sentence Intelligibility	Distance in Meters for 95% Sentence Intelligibility	% of Population Highly Annoyed[3]		
75 and above	May Begin to Occur	98%	0.5	37%	Very Severe	Noise is likely to be the most important of all adverse aspects of the community environment.
70	Will Not Likely Occur	99%	0.9	25%	Severe	Noise is one of the most important adverse aspects of the community environment.
65	Will Not Occur	100%	1.5	15%	Significant	Noise is one of the important adverse aspects of the community environment.
60	Will Not Occur	100%	2.0	9%	Moderate to Slight	Noise may be considered an adverse aspect of the community environment.
55 and below	Will Not Occur	100%	3.5	4%		Noise considered no more important than various other environmental factors.

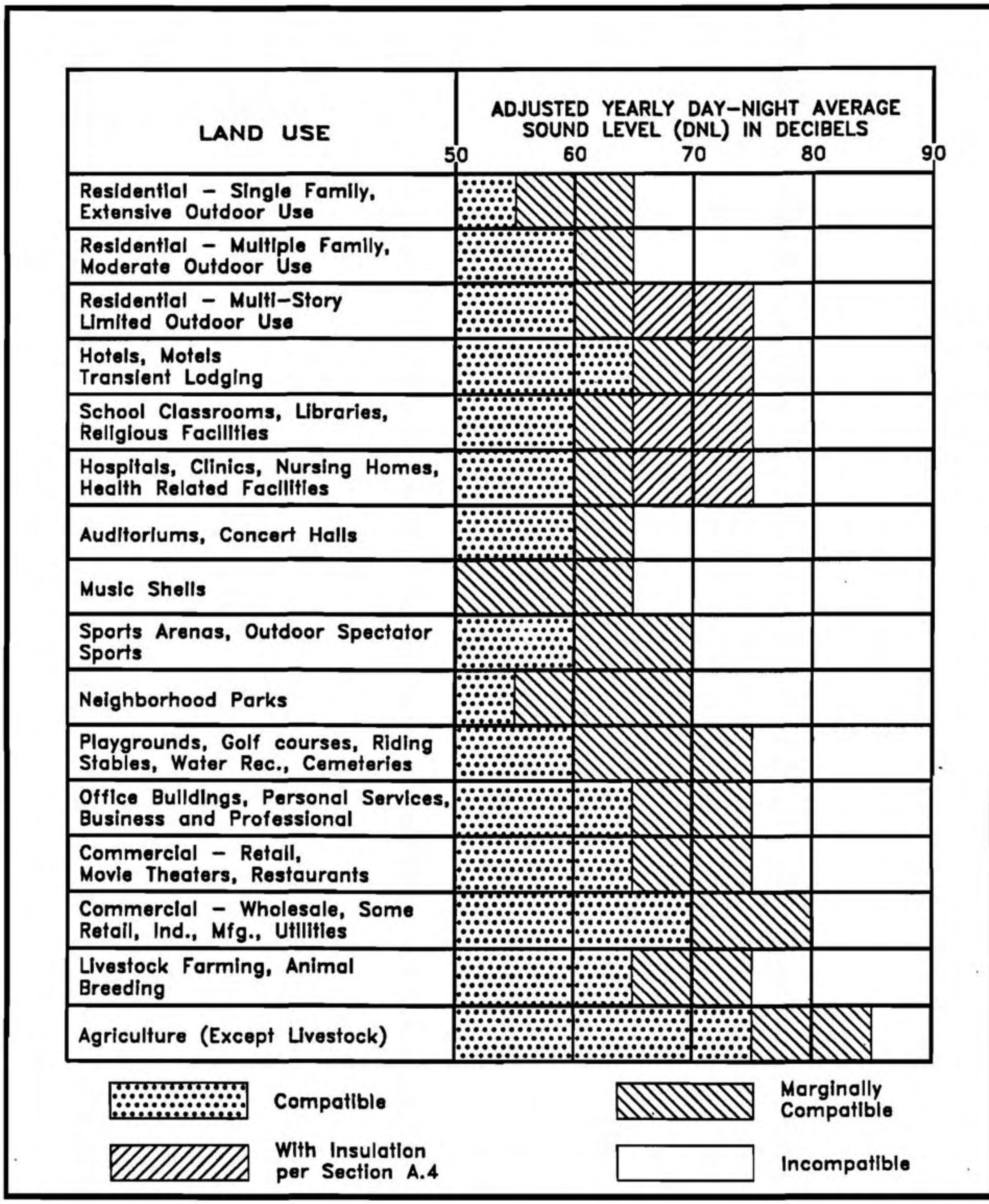
1. "Speech Interference" data are drawn from the following tables in EPA's "Levels Document": Table 3, Fig. D-1, Fig. D-2, Fig. D-3. All other data from National Academy of Science 1977 report "Guidelines for Preparing Environmental Impact Statements on Noise, Report of Working Group 69 on Evaluation of Environmental Impact of Noise."

2. Depends on attitudes and other factors.

3. The percentages of people reporting annoyance to lesser extents are higher in each case. An unknown small percentage of people will report being "highly annoyed" even in the quietest surroundings. One reason is the difficulty all people have in integrating annoyance over a very long time.

4. Attitudes or other non-acoustic factors can modify this. Noise at low levels can still be an important problem, particularly when it intrudes into a quiet environment.

NOTE: Research implicates noise as a factor producing stress-related health effects such as heart disease, high-blood pressure and stroke, ulcers and other digestive disorders. The relationships between noise and these effects, however, have not as yet been quantified.

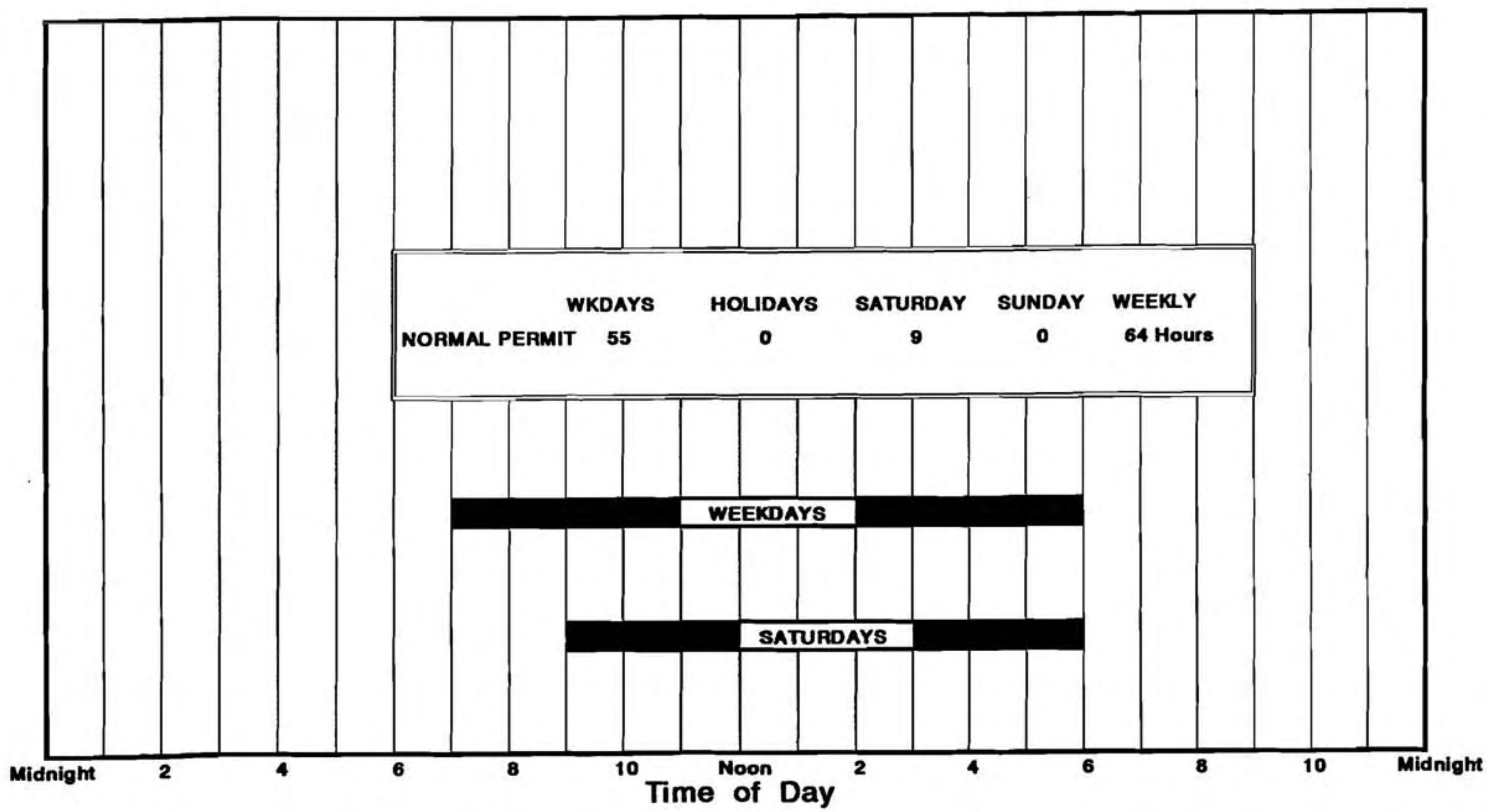


LAND USE COMPATIBILITY WITH YEARLY AVERAGE DAY-NIGHT AVERAGE SOUND LEVEL (DNL) AT A SITE FOR BUILDINGS AS COMMONLY CONSTRUCTED.
(Source: American National Standards Institute S12.9–1998/Part 5)

FIGURE 2

noise during limited time periods. The limited time periods normally permitted are the daytime hours on weekdays and Saturdays, with noisy construction activities not permitted on Sundays and holidays (see FIGURE 3). State DOH noise regulations are expressed in maximum allowable property line noise limits rather than DNL (see Reference 5). Al- though they are not directly comparable to noise criteria expressed in DNL, State DOH noise limits for residential, commercial, and industrial lands equate to approximately 55, 60, and 76 DNL, respectively.

Where construction work is required during the evening or nighttime hours, or on Sundays or holidays, the granting of a noise variance is possible from the State DOH whenever the broader public interests are served by the variance. Examples of construction activities where noise variances have been granted for work during the nighttime, Sunday, or holiday periods are: highway repaving and reconstruction, work on bridges which cross over highways, sewer line rehabilitation, sewer manhole rehabilitation, water line rehabilitation, and electrical facility repairs and installation. In general, construction work is performed during the evening or nighttime hours, or on Sundays or holidays because of less traffic congestion during those periods, or because of the need to perform certain types of specialized construction work (cured-in-place pipe lining, or high voltage cable splicing) around-the-clock.



AVAILABLE WORK HOURS UNDER DOH PERMIT PROCEDURES FOR CONSTRUCTION NOISE

FIGURE 3

CHAPTER IV. GENERAL STUDY METHODOLOGY

Reference 6 was used to identify a total of seven possible options for construction of the new Force Main No. 2 between the Kaneohe Wastewater Pump Station (WWPS) and the Kailua Wastewater Treatment Plant (WWTP) using trenchless methods. Each of these options were then used to identify the possible locations of noise producing construction equipment in the Kaneohe Bay environs. Every trenchless option involved the construction of an underground sewer line below Kaneohe Bay between the Waikalua Loko Fishpond on Kaneohe WWPS side of Kaneohe Bay and the H-3, Kaneohe Bay Drive Interchange on the Kailua WWTP side of Kaneohe Bay. It should be noted that for all of the trenchless options, a short section of sewer line will be constructed between the H-3, Kaneohe Bay Drive Interchange and the Kailua WWTP using the conventional open trench method, as well as between the Kaneohe WWPS and the Kaneohe end of the underbay sewer line. For each underbay option, the potential noise impacts associated with the option were described.

Existing evening, nighttime, and early morning background noise levels were measured at six locations (A, B, C, D, E, and F) in the project environs to provide a basis for describing the existing background noise levels at noise sensitive receptors in the project environs. The locations of the measurement sites are shown in FIGURE 1. Noise measurements were performed during the months of December 2008 and October 2009. The results of the background noise measurements were compared with calculations of predicted noise levels during construction activities which may occur during the project.

More emphasis was placed on describing the nighttime noise levels in the project environs, because of the probable need to perform some phases of construction during the nighttime hours. During the daytime hours between 7:00 am and 6:00 pm on weekdays (excluding holidays), and between 9:00 am to 6:00 pm on Saturdays, construction activities are normally permitted under the State DOH noise regulations (see FIGURE 3). Mitigation of construction noise during those normally permitted periods are less critical to the progress of the work, because they tend to occur during the daytime hours of the day when most residents are awake. During the nighttime period, when most residents are asleep, there are increased risks of annoyance and sleep interference when construction occurs during the night. If the noise from construction activities does not exceed normal background noise levels, risks of adverse noise impacts from the construction activities will tend to be much lower than if the construction noise was much higher than the normal background noise levels.

For this project, the State DOH noise limits of 55 dBA during the daytime (7:00 am to 10:00 pm) and 45 dBA during the nighttime (10:00 pm to 7:00 am) were also used as the thresholds for evaluating potential noise impacts. As shown in FIGURE 1, essentially all of the developed lands in the Kaneohe Bay environs are zoned for single family residential or preservation uses. So these daytime and nighttime noise thresholds are consistent with the property line limits of Reference 5. It should be noted that these thresholds are being used for the purposes of this study, since the State

DOH typically applies these noise limits only to fixed machinery, and not to other mobile or portable noise sources which are used in construction, and which are regulated using the DOH construction noise permitting process.

In addition to the State DOH 55 dBA and 45 dBA noise limits for single family residential and preservation uses, the FHA/HUD noise standard of 65 DNL was also used to evaluate potential noise impacts from heavy truck traffic to and from the Kaneohe WWPS construction site. The 65 DNL standard was also used to establish the recommended noise limits for construction noise from fixed machinery and equipment at the closest residences to the construction sites.

The potential noise levels at residences in the Kaneohe Bay area during construction of Force Main No. 2 using trenchless methods were estimated in order to evaluate the potential noise impacts which may occur during construction. It is expected that most of the work will be performed during the normally permitted daytime hours on weekdays and Saturdays. Those potential noise impacts which were common to all trenchless construction options were identified, as were those potential noise impacts which were unique to specific construction options.

Recommendations for mitigating potential noise impacts were also provided for construction activities during the normally permitted daytime construction period as well as for construction activities which would be required during the nighttime, holiday, or Sunday construction periods.

V. EXISTING ACOUSTICAL ENVIRONMENT

Because the coastline of Kaneohe Bay is removed from the major roadways (Kaneohe Bay Drive, H-3 Freeway, and Kamehameha Highway), the existing background ambient noise levels within the project environs are relatively low and controlled by the sounds of natural and human activities, and distant traffic and local traffic on roadways in the project area. The natural sounds could include the sound of surf, birds, animals, insects, and foilage moving with the wind. The sounds of human activities could include lawn mowers, leaf blowers, music, home construction, and conversations. Background noise levels during the daytime tend to be higher with intermittent excursions to the 60 or 80 dBA level during intermittent noise events, while background noise levels during the nighttime tend to be lower and drop to levels below 30 dBA during the quietist periods.

TABLE 3 presents the results of the nighttime background noise measurements at Locations A, B, and D through F. FIGURE 4 is a strip chart of background noise levels continuously recorded at Location C in December 2008. The measurement results indicate that residents along the shoreline of Kaneohe Bay probably experience relatively low levels of background noise during the nighttime period, particularly when they are located away from or are shielded from the major roadways. Existing average background noise levels during the daytime hours are probably in the range of 55 to 60 dBA, and existing average background noise levels during the nighttime hours are probably in the range of 35 to 45 dBA, and are probably similar to the State DOH property line noise limits of 55 dBA and 45 dBA for the daytime and nighttime periods, respectively.

Along the major roadways in the project area, such as Kaneohe Bay Drive, existing background noise levels are controlled by traffic noise. At approximately 50 feet from the centerline of Kaneohe Bay Drive, traffic noise levels range from 72 to 86 dBA during motor vehicle passbys, with average noise levels ranging from 56 to 66 dBA. Traffic noise levels tend to be highest at the first row of dwellings which front the roadway, and diminish at dwellings which are further removed from the roadway or which are shielded by the terrain and structures which block the visual line of sight between the dwelling and roadway vehicles. Traffic noise levels tend to be highest during the daytime hours, increasing rapidly during the morning commuting period, remaining relatively constant during the daytime hours, increasing slightly during the afternoon commuting period, and decreasing during the evening and nighttime period to its lowest level at 3:30 to 4:30 am.

Existing background noise levels in the project environs are too low to mask the noise from typical sewer force main construction activities, whether they involve open trenching or trenchless methods. So, as is typical in essentially all areas where construction activities occur, construction noise is typically audible, irrespective of the existing background noise levels. And in the project environs, where background noise

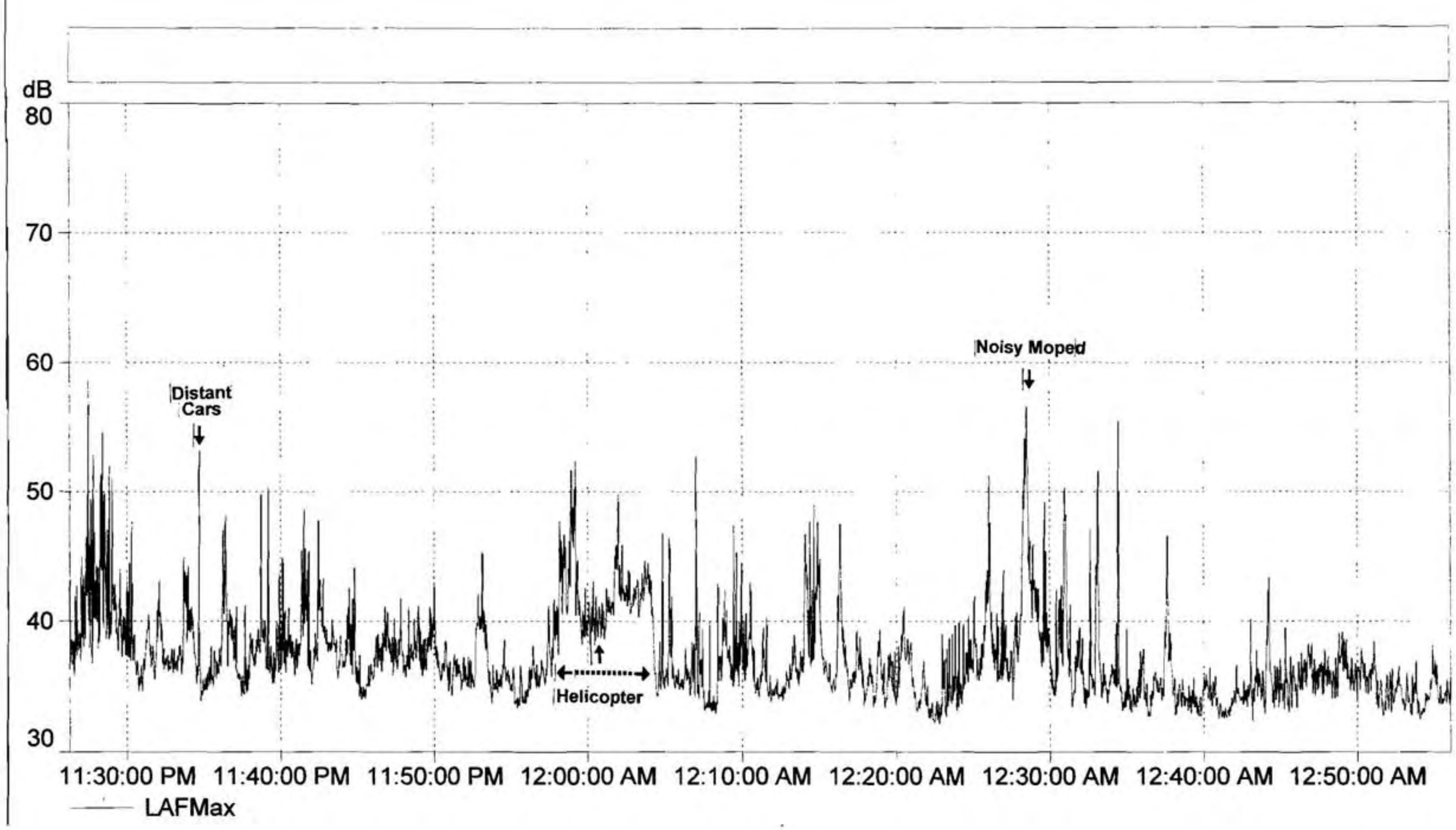
TABLE 3
SUMMARY OF MEASURED BACKGROUND NOISE LEVELS AT VARIOUS LOCATIONS

LOCATION: KANEOHE BAY FOR KANEOHE / KAILUA FORCE MAIN NO. 2
DATE: October 22-23, 2009

Start Time	End Time		Leq	Lmax	Lmin	L1	L10	L50	L90	L99	Event Description
Location "A" - Kahanahou Place											
1858	1913		51.9	72.1	46.1	60.0	54.1	50.6	47.9	46.6	
2144	2159		53.6	72.9	46.3	60.3	56.8	51.7	48.7	47.2	
2347	0002		40.9	59.8	31.4	49.3	45.4	36.2	32.9	31.9	
0156	0211		31.9	54.2	28.4	37.5	33.4	31.4	29.7	28.8	
0353	0408		44.9	70.4	29.9	58.5	39.4	34.1	32.3	30.8	
Location "B" - Waikalua Road, Kaneohe Beach Park											
1924	1939		48.7	68.6	43.3	56.8	51.5	46.7	44.7	43.5	
2121	2136		45.6	70.9	39.8	52.6	47.6	44.4	42.1	40.4	
2322	2337		35.9	57.1	31.9	42.0	37.3	34.7	33.2	32.3	
0134	0150		40.4	58.4	34.7	46.5	43.1	39.6	36.6	34.6	
0332	0347		37.1	68.3	29.6	42.7	38.2	34.2	31.5	30.0	
Location "D" - Likeke Place											
1950	2005		54.7	71.3	41.9	60.7	57.0	53.6	50.7	43.8	Loud Music from Nearby Home
2056	2111		55.9	65.9	40.9	60.3	58.0	55.7	52.9	47.0	Loud Music from Nearby Home
											Intermittent Weak Music
0108	0123		41.9	53.7	39.8	46.3	43.3	41.4	40.6	40.0	Music Not Audible
0308	0323		36.3	55.2	31.7	44.0	38.6	34.1	32.5	32.0	
Location "E" - Paku Place											
2035	2050		45.8	61.1	39.6	54.8	48.3	43.9	42.2	41.2	
2234	2249		46.8	71.9	40.0	57.7	46.4	45.0	44.1	40.4	
0046	0101		38.1	62.8	33.9	44.5	39.9	36.8	34.8	34.2	
0247	0302		39.0	54.3	37.2	42.7	40.1	38.6	37.9	37.1	
Location "F" - Aikahi Gardens											
2016	2031		56.3	71.8	40.4	64.8	60.6	52.1	44.3	42.0	
2215	2230		55.1	73.9	37.6	64.9	59.7	49.1	41.0	38.6	
0019	0034		50.1	71.1	34.6	64.0	51.2	38.4	36.1	35.2	
0228	0243		49.7	71.0	32.7	64.0	49.6	38.1	35.2	33.8	

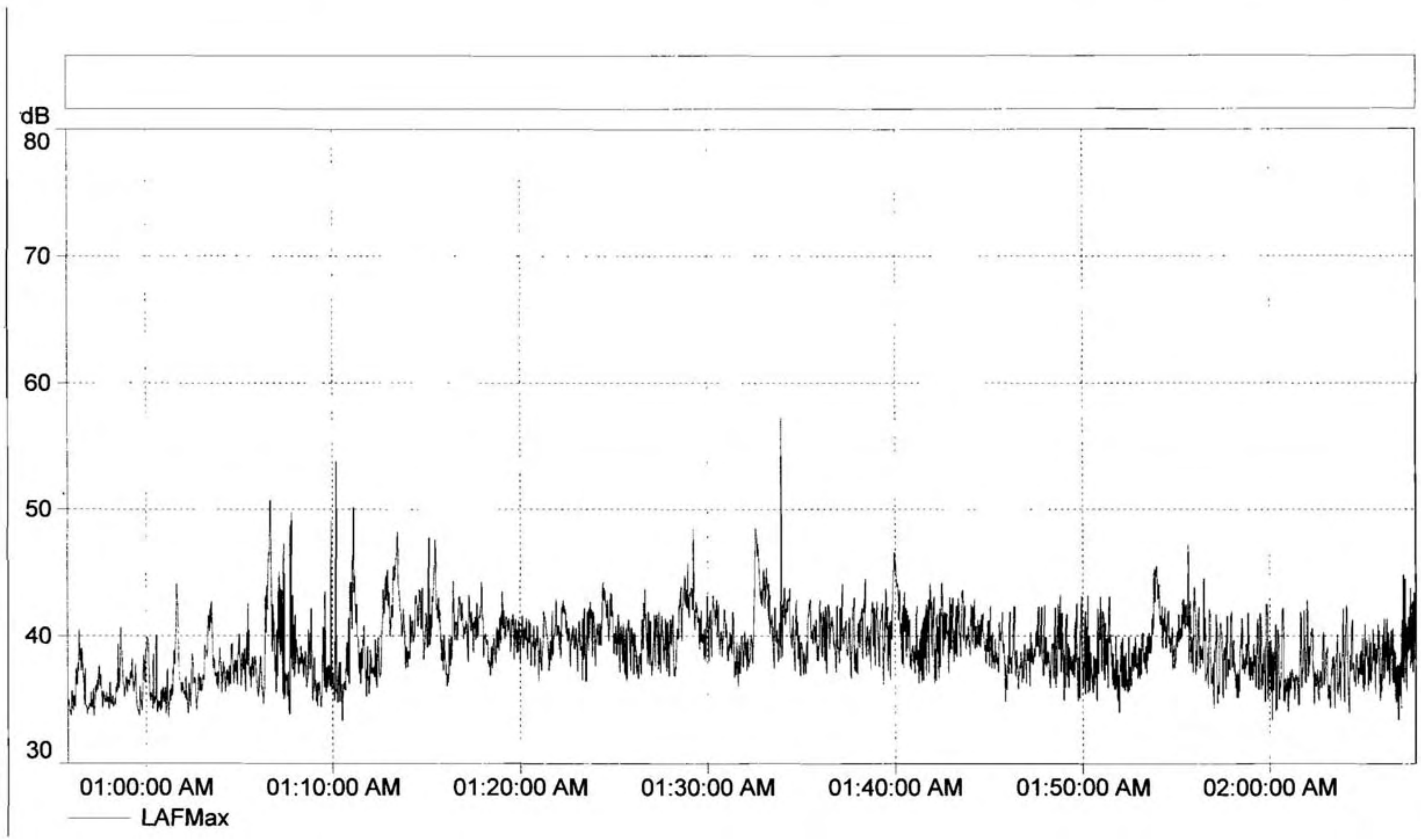
Notes:

a. Leq = Average A-Weighted Sound Level (in dBA)
b. Lmax = Maximum A-Weighted Sound Level (in dBA)
c. Lmin = Minimum A-Weighted Sound Level (in dBA)
d. L10 = A-Weighted Sound Level (in dBA) which was exceeded 10 percent of the time.
e. Lxx = A-Weighted Sound Level (in dBA) which was exceeded xx percent of the time.



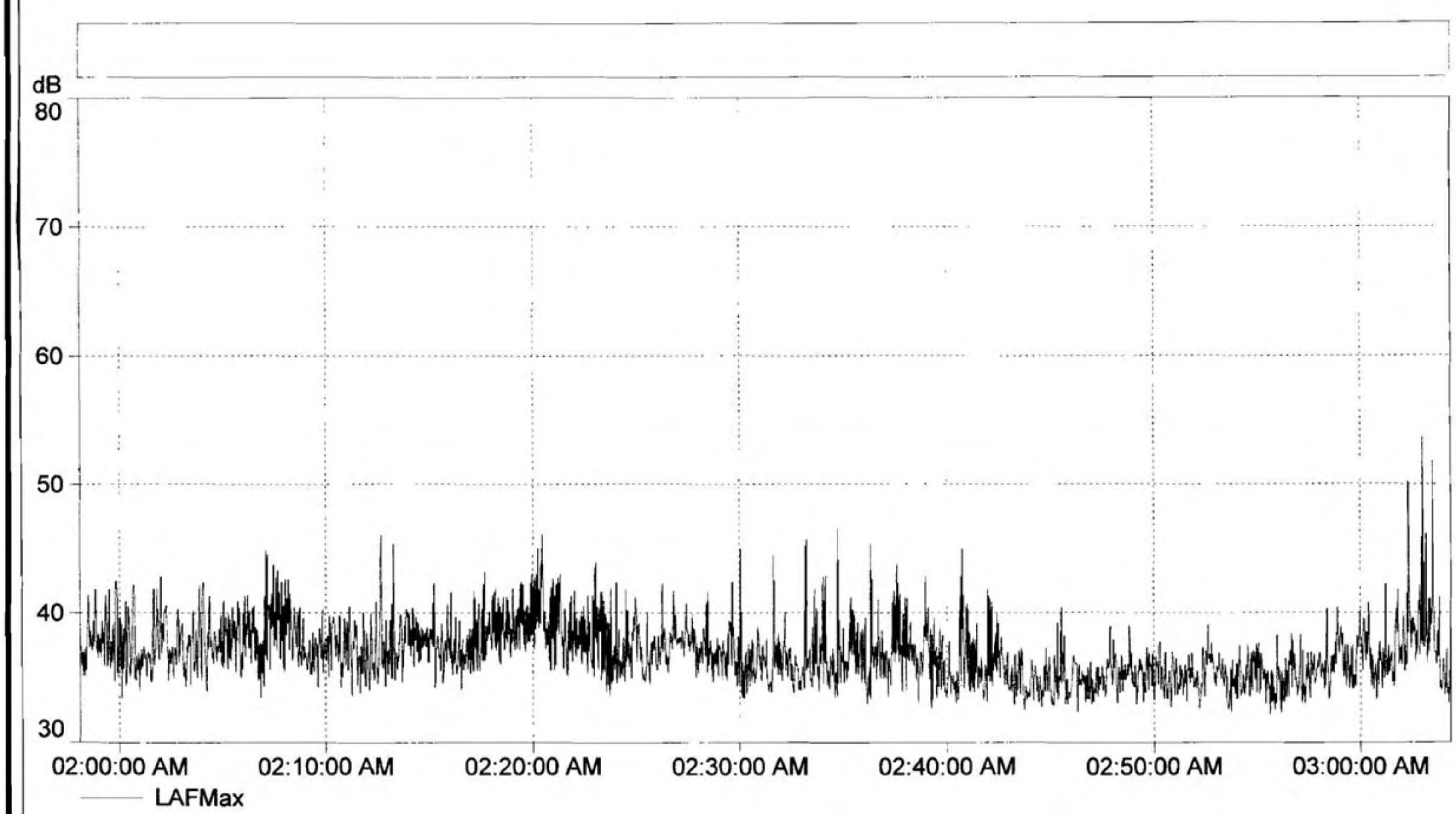
MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION "C"

FIGURE 4



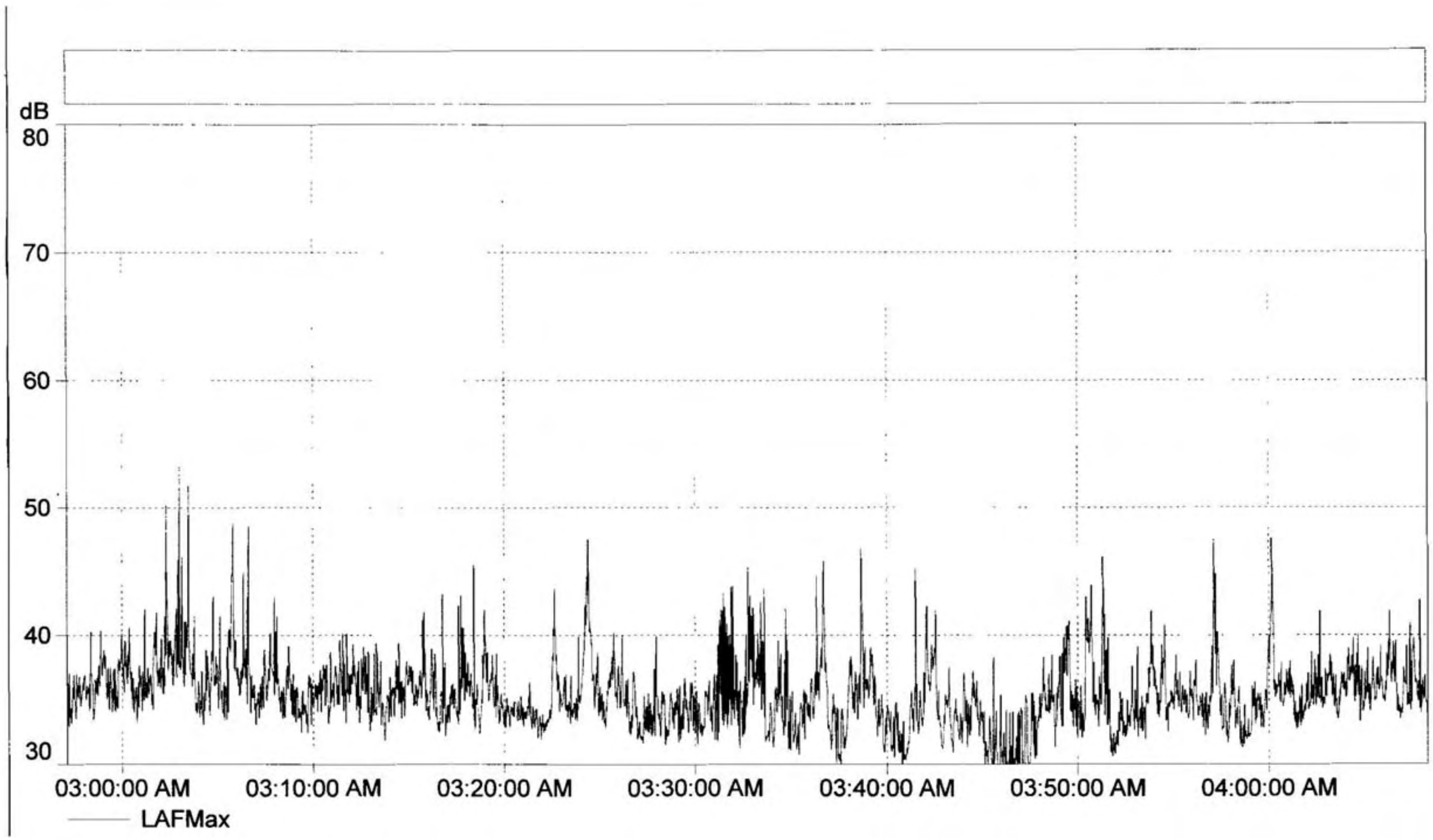
MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA)
AT LOCATION " C "

FIGURE 4(CONT.)



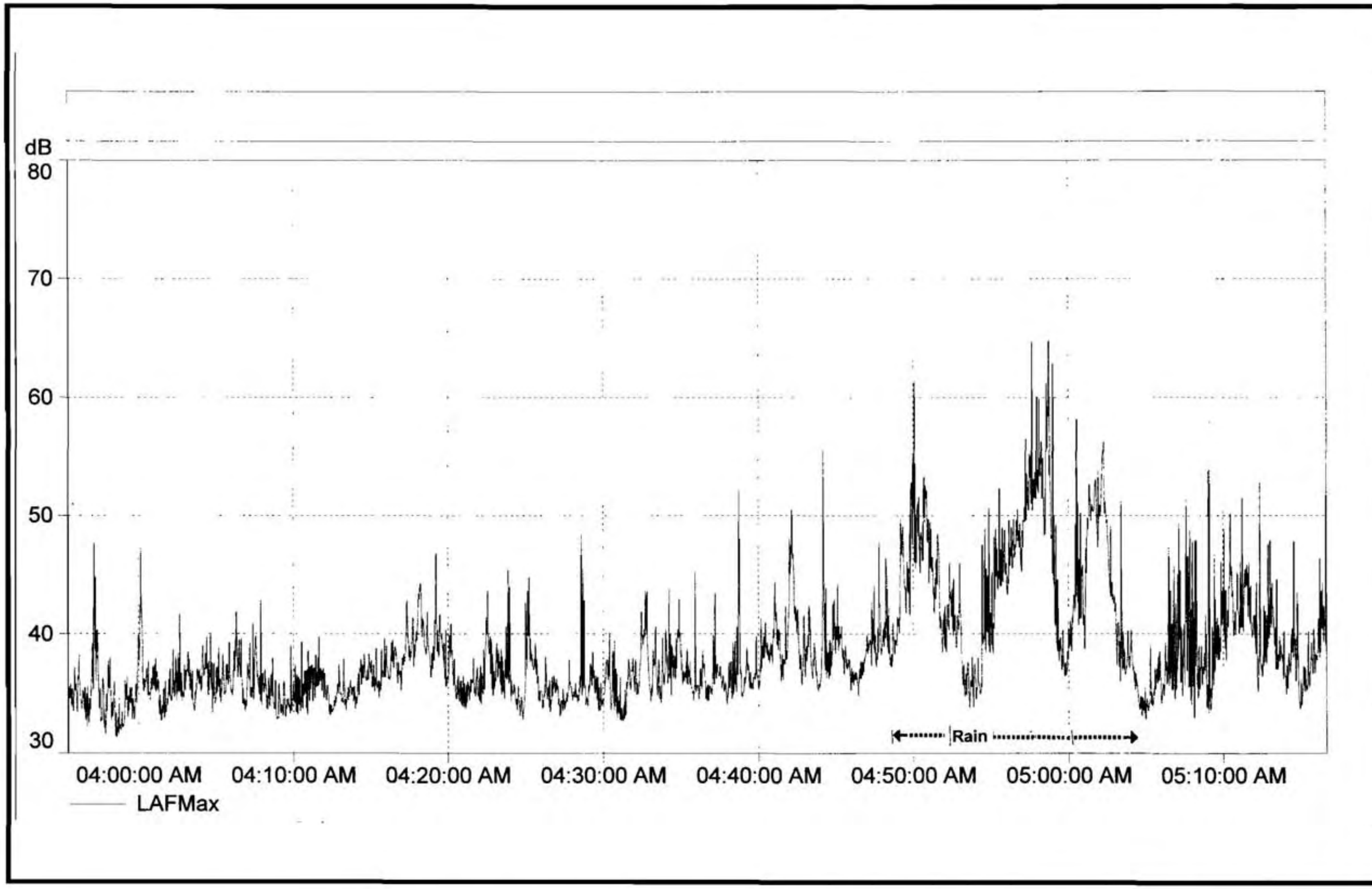
MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION " C "

FIGURE 4(CONT.)



MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION " C "

FIGURE 4(CONT.)



MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION " C "

FIGURE 4(CONT.)

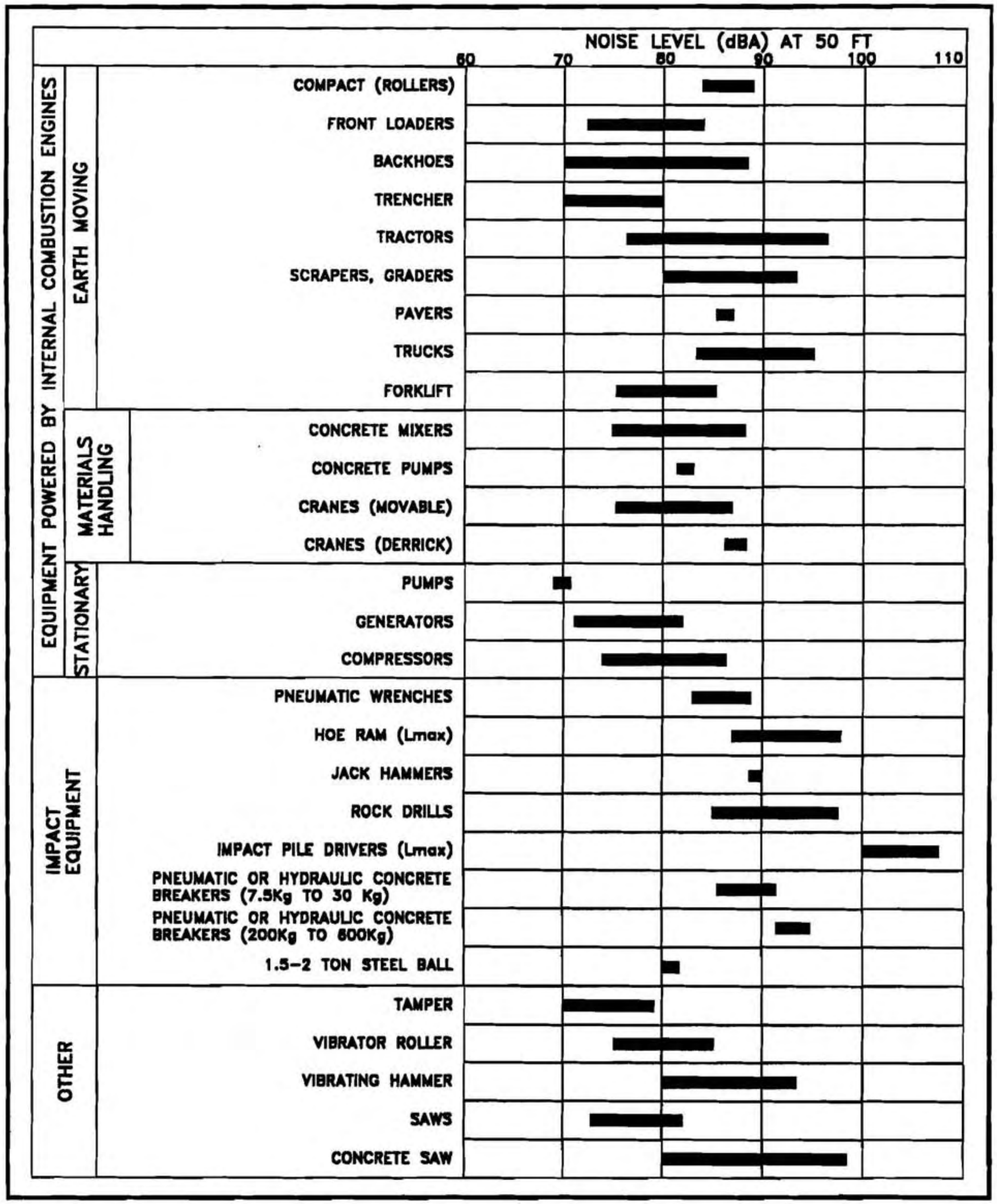
levels are more typical of rural rather than densely populated areas, construction activities will tend to be audible at longer distances from the locations of the construction equipment.

CHAPTER VI. DESCRIPTION OF POTENTIAL FUTURE NOISE LEVELS

General. The potential future noise levels associated with the installation of the Kaneohe / Kailua Force Main No. 2 using trenchless methods are essentially all associated with the activities which could occur during the construction of the force main. Although the trenchless methods examined primarily involved trenchless force main alignments under Kaneohe Bay, construction work above ground will also be required in excavating pits on shore at the Kaneohe and H-3 Interchange ends, as well as in completing overland sections of the force main using the open trench method. In addition, the trucking of spoils from the Kaneohe and H-3 Interchange ends of the underwater sections of the force main to a disposal location in Waianae will be required.

A total of seven options were identified as potential means of constructing the Kaneohe / Kailua Force Main No. 2 under Kaneohe Bay between the Kaneohe Wastewater Pump Station (WWPS) and the Kailua Wastewater Treatment Plant (WWTP). All seven options also include the connection of the two ends of the underwater sections of the force main to the facilities at Kaneohe WWPS and Kailua WWTP using the open trench method. FIGURE 1 depicts the locations of the various underbay force main alignments in relation to the Kaneohe WWPS and Kailua WWTP, and to the surrounding developed areas around Kaneohe Bay. Of the seven options, only one will ultimately be used if the underbay alternative is selected for the final force main construction, and the final one used may also be modified to suite the requirements of the actual construction. For example, the final locations of the launching and receiving pits and underwater shafts may be altered by the contractor performing the work. Nevertheless, this effort attempted to describe the salient features of the potential noise impacts during construction of the force main should the underbay alternative be selected.

Typical noise levels of construction equipment are shown in FIGURE 5 and TABLE 4. The decrease in construction equipment noise with increasing distance from the noisier equipment is shown in FIGURE 6. The primary locations where these equipment noise sources may be operating are: the perimeter of the Waikalua Loko Fish Pond and extending into the Bay View Golf Course; the H-3 Interchange at Kaneohe Bay Drive; and the various overwater locations shown in FIGURE 1 which may be required to shorten the lengths of the pipelines which would need to be pulled underwater. Because the available setback distances between the residences and the construction equipment are relatively small at the Kaneohe and Kailua ends of the underbay section of the force main, relatively high noise levels during construction may be unavoidable, particularly during operations of mobile equipment such as trenchers, loaders, diesel trucks, backhoes, vacuum trucks, and cranes. Fortunately, these mobile equipment tend to operate over shorter intervals of time rather than continuously. The equipment which tend to operate continuously, such as generators, pumps, slurry plant, ventilation fans, etc. are typically fixed at specific locations on the



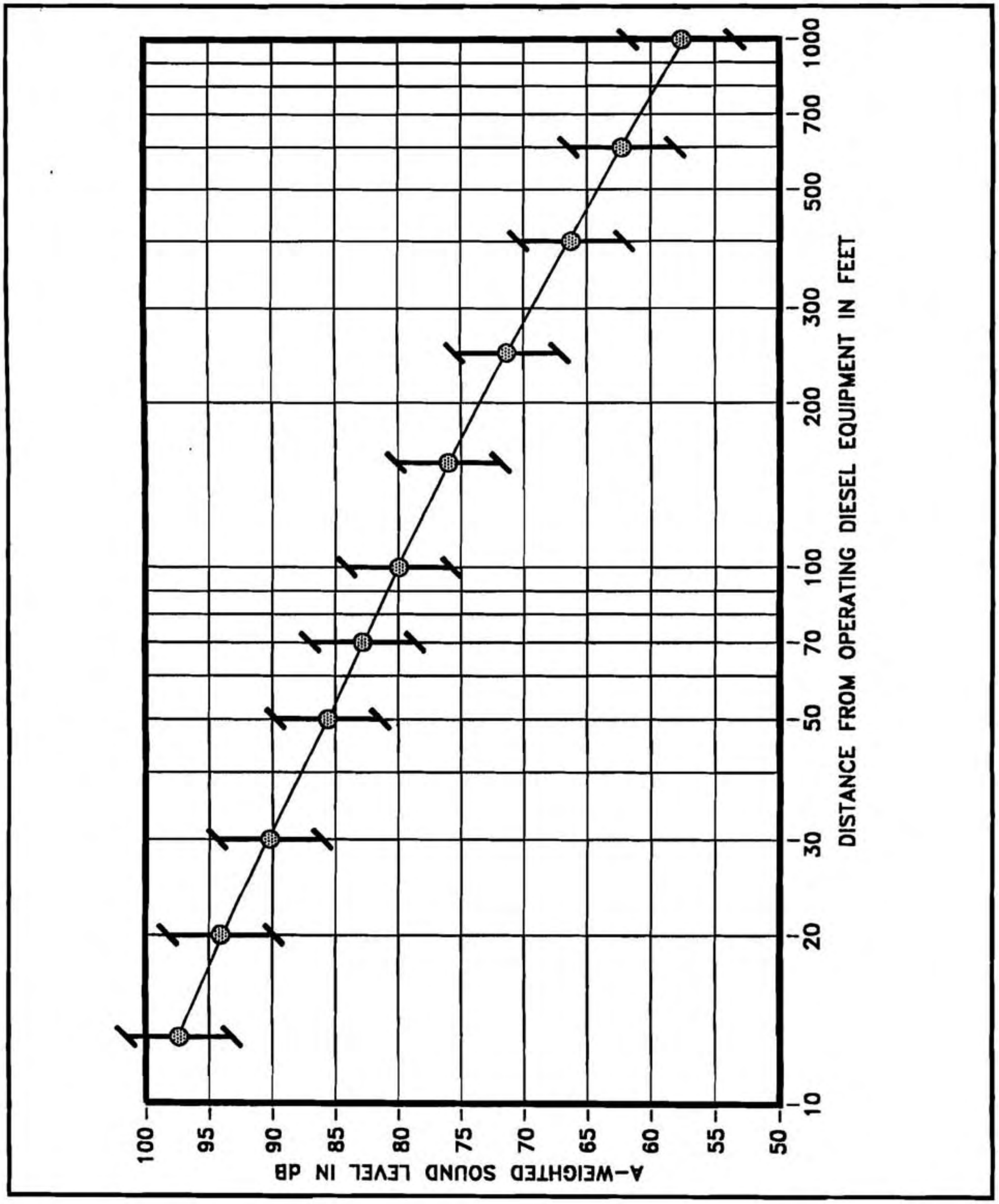
RANGES OF CONSTRUCTION EQUIPMENT NOISE LEVELS

FIGURE 5

TABLE 4

RANGES OF A-WEIGHTED SOUND LEVELS OF CONSTRUCTION EQUIPMENT AT 50 FOOT DISTANCE

EQUIPMENT	SOUND LEVELS (dBA) (Minimum / Maximum)
Excavator	70 / 90
Backhoe	72 / 85
Forklift / Loader	72 / 85
25 Ton Crane	75 / 87
225 KW Generator	67
Trash Pump	70 / 80
Vacuum Truck	72 / 85
80 Ton KRUPP Crane (Quiet)	62 / 73
40 Ton KRUPP Crane	73 / 83
Slurry Plant	70 / 80
Beeper Type Back Up Alarm	86 / 91
Broadband Back Up Alarm	86 / 89



ANTICIPATED RANGE OF CONSTRUCTION NOISE LEVELS VS. DISTANCE

FIGURE 6

construction site, could be fitted with sound attenuation treatment (barriers, enclosures, silencers, etc.), and will typically have lower noise levels than those associated with the mobile construction equipment.

TABLE 5 presents a general overview of the equipment and construction operations which have the potential to cause adverse noise impacts if one of the seven underbay options are implemented. At the Kaneohe WWPS end, the existing residences which surround Bay View Golf Course and Waikalua Loko Fish Pond would have the highest risk of adverse noise impacts from the project. Because of the possible availability of open land at the Kaneohe end of the project for staging of equipment and laydown of pipe, the seven options all include construction activity at the Kaneohe WWPS end of the project. At the H-3 Interchange end of the project, lower risks of adverse noise impacts are expected due to the proximity of the construction site to H-3 Freeway, wider expanse of vacant lands around that site, the difficulties in staging pipe laydown during pullback from that site, and the use of the site for only Tunnel Boring Machine (TBM) recovery instead of launch. At the overwater construction sites, relatively large buffer distances should exist between the operating overwater equipment and the residences along the shoreline. These buffer distances will probably be in excess of 1,500 feet from existing residences, so construction noise from the noisier overwater equipment should be similar to daytime background noise levels at these residences.

<u>Option 1 - HDD Between the Heeia Side of Waikalua Loko Fish Pond and H-3 Interchange</u>. This option involves the use of Horizontal Directional Drilling (HDD) rigs operating at both the Kaneohe and H-3 Interchange ends of the underbay force main. The construction noise sources would be located only at the two ends of the underbay force main. The predicted ranges of construction noise levels at the closest residences to the two construction sites are shown in TABLE 5. The highest noise levels (76 to 79 dBA) are expected to occur at the residences located along Holowai Street on the Heeia side of Waikalua Loko Fishpond. The lowest noise levels (57 to 60 dBA) are expected to occur at residences which are located across the Bay View Golf Course and along Kaneohe Bay Drive.

<u>Option 2 - HDD Between the Heeia Side of Waikalua Loko Fish Pond and H-3 Interchange</u>. This option involves the use of Horizontal Directional Drilling (HDD) rigs operating at both the Kaneohe and H-3 Interchange ends of the underbay force main, with a midbay connection of the force main used to shorten the pipe pullback length through the sediment. The construction noise sources would be located at the two ends of the underbay force main as well as at possible overwater platform locations shown in FIGURE 1. The predicted ranges of construction noise levels at the closest residences to the Kaneohe and H-3 Interchange construction sites are similar to those predicted for Option 1. The highest noise levels (76 to 79 dBA) are expected to occur at the residences located along Holowai Street on the Heeia side of Waikalua Loko Fishpond. The lowest noise levels (57 to 60 dBA) are expected to occur at residences

TABLE 5
SUMMARY OF UNDERBAY OPTIONS 1 THROUGH 7

	************************************* CONSTRUCTION OPERATIONS AND PREDICTED NOISE LEVELS *********************************		
OPTION	KANEOHE / BAY VIEW END	H-3 INTERCHANGE END	OVER WATER BARGES
1	HDD Rig; Cranes during pullback. 76 to 79 dBA @ Heeia Side 57 to 60 dBA @ K-Bay Drive Side	HDD Rig. 68 to 69 dBA @ K-Bay Drive to West 64 to 68 dBA @ Aikahi Gardens to East	None.
2 (Land Rigs)	HDD Rig (Same Noise as Option 1)	HDD Rig (Same Noise as Option 1).	Cranes during pullback. 53 dBA @ shore
2 (Water Rigs)	Cranes during pullback (Similar to Option 1).	Cranes during pullback (Similar to Option 1)	HDD Rigs at two locations. 49 to 52 dBA @ shore
3 (Heeia)	Pit excavation; Microtunneling Drive; Cranes during pullback. 73 to 79 dBA @ Heeia Side 53 to 60 dBA @ K-Bay Drive Side	HDD Rig; and possible pit excavation and Microtunneling Drive. 65 to 71 dBA @ K-Bay Drive to West 61 to 68 dBA @ Aikahi Gardens to East	One or two Work Barges; Recovery Shafts 58 to 62 dBA @ shore
4	Tunnel Boring Machine 74 to 79 dBA @ Heeia Side 54 to 60 dBA @ K-Bay Drive Side	TBM Recovery 72 dBA @ K-Bay Drive to West 69 dBA @ Aikahi Gardens to East	None
5 (YWCA)	Pit excavation; Microtunneling Drive; Cranes during pullback. 55 to 61 dBA @ Heeia Side 68 to 74 dBA @ K-Bay Drive Side	HDD Rig; and possible pit excavation and Microtunneling Drive. (Similar to Option 3)	One or two Work Barges; Recovery Shafts 61 to 62 dBA at shore
6 (YWCA)	Tunnel Boring Machine 56 to 61 dBA @ Heeia Side 69 to 74 dBA @ K-Bay Drive Side	TBM Recovery 72 dBA @ K-Bay Drive to West 69 dBA @ Aikahi Gardens to East	None
7 (WWPS)	Tunnel Boring Machine 60 to 66 dBA @ Heeia Side 60 to 66 dBA @ K-Bay Drive Side	TBM Recovery 72 dBA @ K-Bay Drive to West 69 dBA @ Aikahi Gardens to East	None
All	Open trenching from shore to Kaneohe WWPS	Open trenching from H-3 to Kailua WWTP.	

Notes:
1. Typically, lower noise level is steady source level, and higher noise level is due to intermittent source.
2. Exception occurs when only intermittent sources operate.

which are located across the Bay View Golf Course and along Kaneohe Bay Drive. Predicted noise levels from the overwater platforms at the closest shoreline residences are expected to range between 49 to 53 dBA.

Option 3 - HDD Between the Heeia Side of Waikalua Loko Fish Pond and H-3 Interchange with Microtunneling Segments At One Or Both Ends. This option involves the use of a Horizontal Directional Drilling (HDD) rig operating at the H-3 Interchange end of the underbay force main, with one or two 2,000 foot long Microtunneling Segments used to shorten the pipe pullback lengths through the sediment. The construction noise sources would be located at the two ends of the underbay force main as well as at the two possible overwater platform locations shown in FIGURE 1. The predicted ranges of construction noise levels at the closest residences to the Kaneohe and H-3 Interchange construction sites are similar to those predicted for Options 1 and 2. The highest noise levels (73 to 79 dBA) are expected to occur at the residences located along Holowai Street on the Heeia side of Waikalua Loko Fishpond. The lowest noise levels (53 to 60 dBA) are expected to occur at residences which are located across the Bay View Golf Course and along Kaneohe Bay Drive. Noise levels from the overwater barges will tend to be slightly higher than under Option 2 and range from 58 to 62 dBA at the closest residences along the shoreline.

Option 4 - Tunneling Using Slurry Tunnel Boring Machine (TBM) Between the Heeia Side of Waikalua Loko Fish Pond and H-3 Interchange. This option involves the use of a TBM launched from the same location as Options 1 through 3 at the Heeia side of Waikalua Loko Fishpond, and which follows the same force main alignment to the H-3 Interchange end as Options 1 through 3. The primary construction noise sources during tunneling operations would be located at the Kaneohe end of the alignment where shown in FIGURE 1, with predicted noise levels of 74 to 79 dBA at the residences along Holowai Street and 54 to 60 dBA at the residences which are located across the Bay View Golf Course and along Kaneohe Bay Drive. Construction noise levels during TBM recovery operations at the H-3 Interchange end of the alignment are predicted to range from 72 dBA at the closest residences to the west to 69 dBA at Aikahi Gardens residents to the east of the H-3 Interchange TBM recovery area.

Option 5 - HDD Between the YWCA Side of Waikalua Loko Fish Pond and H-3 Interchange with Microtunneling Segments At One Or Both Ends. This option is similar to Option 3 and involves the use of a Horizontal Directional Drilling (HDD) rig operating at the H-3 Interchange end of the underbay force main, with one or two 2,000 foot long Microtunneling Segments used to shorten the pipe pullback lengths through the sediment. This option differs from Option 3 in the alignment of the force main as well as the location of the Microtunneling Pit at the Kaneohe end (see FIGURE 1). The construction noise sources would be located at the two ends of the underbay force main as well as at the two possible overwater platform locations shown in FIGURE 1. The predicted ranges of construction noise levels at the closest residences to the H-3 Interchange construction site are similar to those predicted for Option 3. The highest noise levels (68 to 74 dBA) are expected to occur at the residences located along the Bay View Golf Course on the YWCA side of Waikalua Loko Fishpond. The lowest noise levels (55 to 61 dBA) are expected to occur at residences which are located along Holowai Street on the Heeia side of Waikalua Loko Fishpond. Noise levels from the overwater barges will tend to be slightly higher than under Option 3 and range from 61 to 62 dBA at the closest residences along the shoreline.

Option 6 - Tunneling Using Slurry Tunnel Boring Machine (TBM) Between the YWCA Side of Waikalua Loko Fish Pond and H-3 Interchange. This option involves the use of a TBM launched from the same location as Option 5 at the YWCA side of Waikalua Loko Fishpond, and which follows the same force main alignment to the H-3 Interchange end as Option 5. The primary construction noise sources during tunneling operations would be located at the Kaneohe end of the alignment where shown in FIGURE 1, with predicted noise levels of 56 to 61 dBA at the residences along Holowai Street and 69 to 74 dBA at the residences which are located across the Bay View Golf Course and along Kaneohe Bay Drive. Construction noise levels during TBM recovery operations at the H-3 Interchange end of the alignment are predicted be similar to those under Option 4, and to range from 72 dBA at the closest residences to the west to 69 dBA at Aikahi Gardens residents to the east of the H-3 Interchange TBM recovery area.

Option 7 - Tunneling Using Slurry Tunnel Boring Machine (TBM) Between the Bay View Golf Course Side of Waikalua Loko Fish Pond and H-3 Interchange. This option involves the use of a TBM launched from a location further inland and on the Bay View Golf Course side of Waikalua Loko Fishpond, and which follows a more direct force main alignment to the H-3 Interchange end as shown in FIGURE 1. The primary construction noise sources during tunneling operations would be located at the Kaneohe end of the alignment where shown in FIGURE 1, with predicted noise levels of 60 to 66 dBA at the residences along Holowai Street as well as at the residences which are located across the Bay View Golf Course and along Kaneohe Bay Drive. Construction noise levels during TBM recovery operations at the H-3 Interchange end of the alignment are predicted be similar to those under Options 4 and 6, and to range from 72 dBA at the closest residences to the west to 69 dBA at Aikahi Gardens residents to the east of the H-3 Interchange TBM recovery area.

Open Trenching Operations. Construction noise levels during open trenching operations are anticipated to be similar to those shown in FIGURE 5, and range between 80 to 90 dBA at 50 feet distance from the operating equipment. Those residences which are within direct lines-of-sight and which are closest to the construction equipment will tend to experience the highest noise levels as indicated in FIGURE 5. Force main construction using the open trenching method are expected to occur between the Kaneohe end of the underwater pipeline or tunnel to the Kaneohe WWPS, and between the H-3 Interchange end of the underwater pipeline or tunnel to the Kailua WWTP. The final location of the open trenching work at the Kaneohe WWPS end will depend on which of the seven underbay options is selected. The final location of the open trenching work at the Kailua WWTP end will follow the Kaneohe Bay Drive Right-of-Way between the H-3 Interchange end of the underbay force main and the Kaneohe WWPS.

<u>Spoils Transporting Truck Operations</u>. Materials excavated from under Kaneohe Bay will be collected at the Kaneohe end and possibly at the H-3 Interchange end of the selected underbay force main alignment. These materials (or spoils) will need to be transported to a landfill site in Waianae using dump trucks at a maximum frequency of 6 loads per hour from each of the two ends of the underbay force main alignment.

The maximum noise level during the truck passby may be as high as 90 dBA at 50 feet and 94 dBA at 25 feet distance from the roadway centerline. At a total of 12 (6 inbound plus 6 outbound) heavy truck trips per hour, the average hourly noise level from the truck trips could be as high as 65 Leq(h) at 50 feet, and 69 Leq(h) at 25 feet from the roadway centerline. Assuming that this rate of heavy truck traffic is maintained for 8 hours per day, the average DNL value of the truck noise is predicted to range between 60 DNL at 50 feet to 64 DNL at 25 feet from the roadway centerline.

The heavy truck route between Kaneohe Bay Drive and the Kaneohe WWPS may be along Puohala and Kulauli Streets, which passes through residential areas. This situation is considered to have the worst case potential for adverse noise impacts from heavy truck traffic due to the relatively short setback distances to the residences and because of the relatively lower levels of existing traffic and background noise along these two streets. The typical setback distances from the centerlines of these streets to the residences range from approximately 35 to 55 feet. Therefore, predicted noise levels during an 8 hour materials hauling day from the heavy truck traffic could range from 60 to 64 DNL. These levels are below the FHA/HUD noise standard of 65 DNL for residences, and should be below the federally accepted threshold for adverse noise impact.

CHAPTER VII. DISCUSSION OF PROJECT-RELATED NOISE IMPACTS AND POSSIBLE MITIGATION MEASURES

General Construction Noise. Audible construction noise will probably be unavoidable during the entire project construction period. The total time period for actual construction is estimated to be approximately two years, with most of the work being performed during the normally permitted hours of 7:00 am to 6:00 pm on weekdays, and between 9:00 am to 6:00 pm on Saturdays. Actual length of exposure to construction noise at any receptor location will probably be less than the total construction period for the entire project. Typical levels of exterior noise from construction activity at the closest residential receptors for the various underbay construction options were described in Chapter VI, and are summarized in TABLE 5 and FIGURE 5. Construction noise levels will be audible at the closest residences, and will exceed existing daytime background noise levels by 10 to 25 dBA. Typical levels of construction noise inside naturally ventilated and air conditioned structures are approximately 10 and 20 dBA less, respectively, than the levels shown in TABLE 5 and FIGURE 5.

Mitigation of construction noise to inaudible levels will not be practical in all cases due to the intensity of construction noise sources (80 to 90+ dBA at 50 FT distance), and due to the exterior nature of the work (excavating, grading and earth and spoils moving, trenching, crane operations, hammering, etc.). The use of properly muffled construction equipment should be required on the job site. The anticipated noise levels during actual construction activities are typical of other construction activities (exterior earthwork, open trenching, or building erection). Option 7, which locates the Tunnel Boring Machine launch site at the furthest distance from the closest residences is predicted to result in the least noise impacts, primarily due to the larger buffer distances to the closest residences, and the minimal construction activities required at the H-3 Interchange site. This option also provides the opportunity for nighttime and weekend work with the lowest risk of adverse noise impacts.

Possible Noise Mitigation Measures. Noise mitigation measures should be included in the Force Main No. 2 project if the underbay trenchless construction alternative is selected. The following noise mitigation measures are recommended for inclusion within the project construction documents:

1. Provide sound attenuation treatments to reduce all steady, continuous noise sources (generators, pumps, plants, fans, etc.) which operate during the normally permitted daytime hours so that they do not exceed 65 dBA at the closest residences.

2. Select the underbay option which requires the least amount of construction during the nighttime or weekend periods, and which would require the issuance of a noise variance by the State DOH. Alternately, require that fixed machinery used in nighttime or weekend work during the noise variance periods do not exceed 45 dBA at the closest residences.

3. Require the installation and use of broadband back-up alarms in place of beeper-type back-up alarms for all mobile equipment operating on the project work sites. The broadband alarms should be less audible at the longer distances, and should be less annoying at all distances from the mobile construction equipment. Use broadband alarms which automatically adjust the alarm sound level for differences in background noise level.

4. If prolonged periods of work are required during the non-permitted (or noise variance) hours, consider the use of HECO electrical service drops at the two ends of the underbay force main in place of portable generators and engine driven equipment (pumps, lights, etc.). These service drops may also be used to meet the 65 dBA maximum daytime level recommendation in Paragraph 1, and the 45 dBA nighttime level recommendation in Paragraph 2.

5. Investigate the feasibility of adding an alternate truck route between Kaneohe Bay Drive and the Kaneohe side construction site for spoils removal.

APPENDIX A. REFERENCES

(1) "Guidelines for Considering Noise in Land Use Planning and Control;" Federal Interagency Committee on Urban Noise; June 1980.

(2) American National Standard, "Sound Level Descriptors for Determination of Compatible Land Use," ANSI S12.9-1998/ Part 5; Acoustical Society of America.

(3) "Environmental Criteria and Standards, Noise Abatement and Control, 24 CFR, Part 51, Subpart B;" U.S. Department of Housing and Urban Development; July 12, 1979.

(4) "Information on Levels of Environmental Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety;" U.S. Environmental Protection Agency; EPA 550/9-74- 004; March 1974.

(5) "Title 11, Administrative Rules, Chapter 46, Community Noise Control;" Hawaii State Department of Health; September 23, 1996.

(6) "Design Alternatives Report for Kaneohe / Kailua Force Main No. 2;" Austin, Tsutsumi & Associates, Inc.; January 29, 2010.

APPENDIX B

EXCERPTS FROM EPA'S ACOUSTIC TERMINOLOGY GUIDE

Descriptor Symbol Usage

The recommended symbols for the commonly used acoustic descriptors based on A-weighting are contained in Table I. As most acoustic criteria and standards used by EPA are derived from the A-weighted sound level, almost all descriptor symbol usage guidance is contained in Table I.

Since acoustic nomenclature includes weighting networks other than "A" and measurements other than pressure, an expansion of Table I was developed (Table II). The group adopted the ANSI descriptor-symbol scheme which is structured into three stages. The first stage indicates that the descriptor is a level (i.e., based upon the logarithm of a ratio), the second stage indicates the type of quantity (power, pressure, or sound exposure), and the third stage indicates the weighting network (A, B, C, D, E.....). If no weighting network is specified, "A" weighting is understood. Exceptions are the A-weighted sound level and the A-weighted peak sound level which require that the "A" be specified. For convenience in those situations in which an A-weighted descriptor is being compared to that of another weighting, the alternative column in Table II permits the inclusion of the "A". For example, a report on blast noise might wish to contrast the LCdn with the LAdn.

Although not included in the tables, it is also recommended that "Lpn" and "LepN" be used as symbols for perceived noise levels and effective perceived noise levels, respectively.

It is recommended that in their initial use within a report, such terms be written in full, rather than abbreviated. An example of preferred usage is as follows:

The A-weighted sound level (LA) was measured before and after the installation of acoustical treatment. The measured LA values were 85 and 75 dB respectively.

Descriptor Nomenclature

With regard to energy averaging over time, the term "average" should be discouraged in favor of the term "equivalent". Hence, Leq, is designated the "equivalent sound level". For Ld, Ln, and Ldn, "equivalent" need not be stated since the concept of day, night, or day-night averaging is by definition understood. Therefore, the designations are "day sound level", "night sound level", and "day-night sound level", respectively.

The peak sound level is the logarithmic ratio of peak sound pressure to a reference pressure and not the maximum root mean square pressure. While the latter is the maximum sound pressure level, it is often incorrectly labelled peak. In that sound level meters have "peak" settings, this distinction is most important.

"Background ambient" should be used in lieu of "background", "ambient", "residual", or "indigenous" to describe the level characteristics of the general background noise due to the contribution of many unidentifiable noise sources near and far.

With regard to units, it is recommended that the unit decibel (abbreviated dB) be used without modification. Hence, DBA, PNdB, and EPNdB are not to be used. Examples of this preferred usage are: the Perceived Noise Level (Lpn was found to be 75 dB. Lpn = 75 dB). This decision was based upon the recommendation of the National Bureau of Standards, and the policies of ANSI and the Acoustical Society of America, all of which disallow any modification of bel except for prefixes indicating its multiples or submultiples (e.g., deci).

Noise Impact

In discussing noise impact, it is recommended that "Level Weighted Population" (LWP) replace "Equivalent Noise Impact" (ENI). The term "Relative Change of Impact" (RCI) shall be used for comparing the relative differences in LWP between two alternatives.

Further, when appropriate, "Noise Impact Index" (NII) and "Population Weighed Loss of Hearing" (PHL) shall be used consistent with CHABA Working Group 69 Report Guidelines for Preparing Environmental Impact Statements (1977).

APPENDIX B (CONTINUED)

TABLE I

A-WEIGHTED RECOMMENDED DESCRIPTOR LIST

	TERM	SYMBOL
1.	A-Weighted Sound Level	L_A
2.	A-Weighted Sound Power Level	L_{WA}
3.	Maximum A-Weighted Sound Level	L_{max}
4.	Peak A-Weighted Sound Level	L_{Apk}
5.	Level Exceeded x% of the Time	L_x
6.	Equivalent Sound Level	L_{eq}
7.	Equivalent Sound Level over Time (T) (1)	$L_{eq(T)}$
8.	Day Sound Level	L_d
9.	Night Sound Level	L_n
10.	Day-Night Sound Level	L_{dn}
11.	Yearly Day-Night Sound Level	$L_{dn(Y)}$
12.	Sound Exposure Level	L_{SE}

(1) Unless otherwise specified, time is in hours (e.g. the hourly equivalent level is $L_{eq(1)}$). Time may be specified in non-quantitative terms (e.g., could be specified a $L_{eq(WASH)}$ to mean the washing cycle noise for a washing machine).

SOURCE: EPA ACOUSTIC TERMINOLOGY GUIDE, BNA 8-14-78,

APPENDIX B (CONTINUED)

TABLE II

RECOMMENDED DESCRIPTOR LIST

TERM	A-WEIGHTING	ALTERNATIVE(1) A-WEIGHTING	OTHER(2) WEIGHTING	UNWEIGHTED
1. Sound (Pressure)(3) Level	L_A	L_{pA}	L_B, L_{pB}	L_p
2. Sound Power Level	L_{WA}		L_{WB}	L_W
3. Max. Sound Level	L_{max}	L_{Amax}	L_{Bmax}	L_{pmax}
4. Peak Sound (Pressure) Level	L_{Apk}		L_{Bpk}	L_{pk}
5. Level Exceeded x% of the Time	L_x	L_{Ax}	L_{Bx}	L_{px}
6. Equivalent Sound Level	L_{eq}	L_{Aeq}	L_{Beq}	L_{peq}
7. Equivalent Sound Level (4) Over Time(T)	$L_{eq(T)}$	$L_{Aeq(T)}$	$L_{Beq(T)}$	$L_{peq(T)}$
8. Day Sound Level	L_d	L_{Ad}	L_{Bd}	L_{pd}
9. Night Sound Level	L_n	L_{An}	L_{Bn}	L_{pn}
10. Day-Night Sound Level	L_{dn}	L_{Adn}	L_{Bdn}	L_{pdn}
11. Yearly Day-Night Sound Level	$L_{dn(Y)}$	$L_{Adn(Y)}$	$L_{Bdn(Y)}$	$L_{pdn(Y)}$
12. Sound Exposure Level	L_S	L_{SA}	L_{SB}	L_{Sp}
13. Energy Average Value Over (Non-Time Domain) Set of Observations	$L_{eq(e)}$	$L_{Aeq(e)}$	$L_{Beq(e)}$	$L_{peq(e)}$
14. Level Exceeded x% of the Total Set of (Non-Time Domain) Observations	$L_{x(e)}$	$L_{Ax(e)}$	$L_{Bx(e)}$	$L_{px(e)}$
15. Average L_x Value	L_x	L_{Ax}	L_{Bx}	L_{px}

(1) "Alternative" symbols may be used to assure clarity or consistency.

(2) Only B-weighting shown. Applies also to C,D,E,.....weighting.

(3) The term "pressure" is used only for the unweighted level.

(4) Unless otherwise specified, time is in hours (e.g., the hourly equivalent level is Leq(1). Time may be specified in non-quantitative terms (e.g., could be specified as Leq(WASH) to mean the washing cycle noise for a washing machine.

Appendix L

Acoustic Study For The Gravity Tunnel Between Kaneohe WWPS And Kailua WWTP

Y. Ebisu & Associates

December 2010

ACOUSTIC STUDY FOR THE GRAVITY TUNNEL BETWEEN KANEOHE WWPS AND KAILUA WWTP

Prepared for:

WILSON OKAMOTO CORPORATION

Prepared by:

Y. EBISU & ASSOCIATES
1126 12th Avenue, Room 305
Honolulu, Hawaii 96816

DECEMBER 2010

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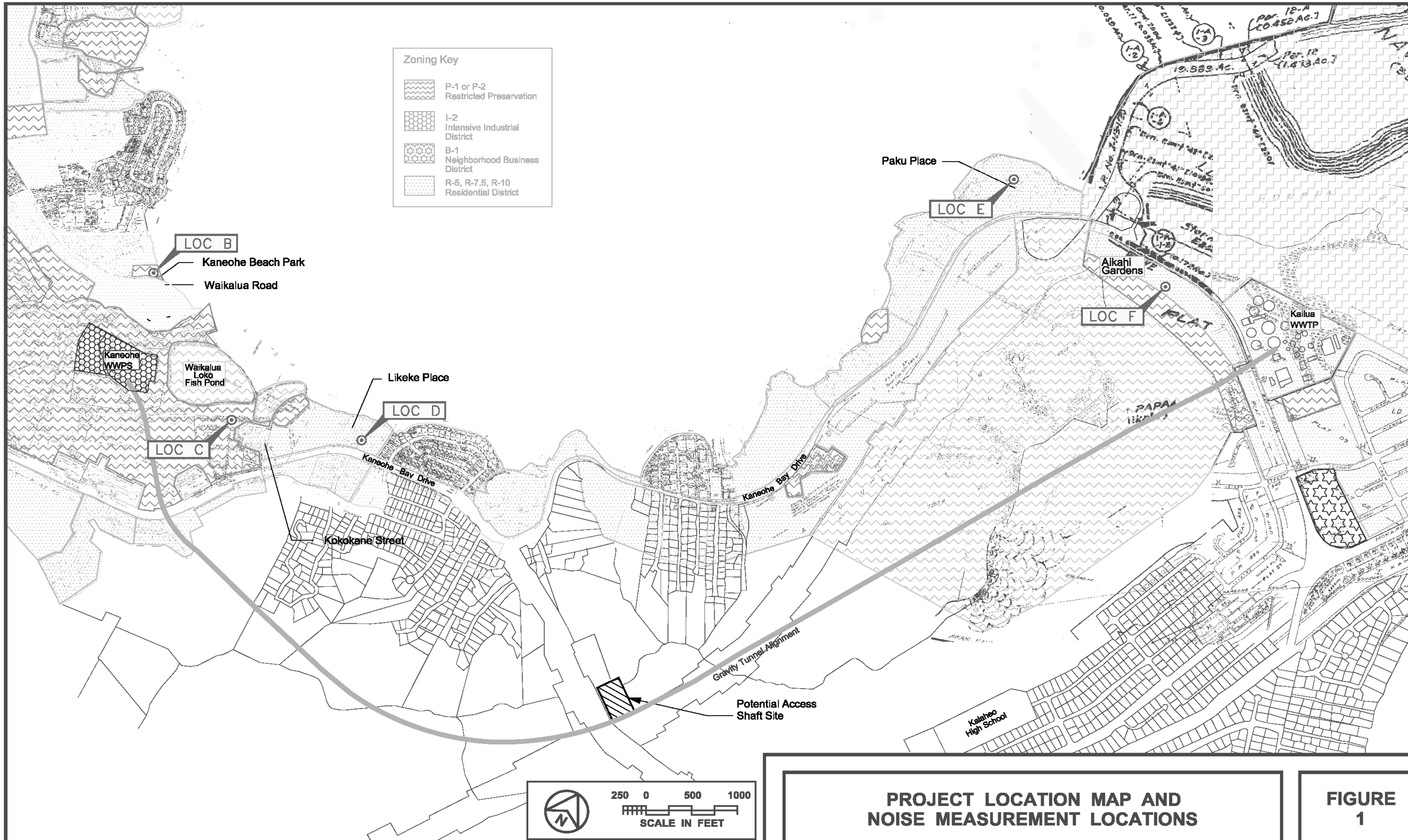
CHAPTER I. SUMMARY

The potential construction noise levels in the vicinity of the Kaneohe / Kailua Gravity Tunnel Alternative's alignment between the Kaneohe Wastewater Pump Station (WWPS) and the Kailua Wastewater Treatment Plant (WWTP) were evaluated for their potential impacts and their relationship to the current FHA/HUD noise standard. The potential construction noise levels associated with the gravity tunnel alternative (see FIGURE 1) were evaluated. In addition, the potential construction noise levels and impacts associated with operations at the tunnel access shafts and the transportation of spoils and materials from the construction sites were evaluated. The potential impacts resulting from ground vibrations during tunneling operations were also evaluated.

The potential noise impacts during tunneling operations between the Kaneohe WWPS and the Kailua WWTP are more dependent on where the tunnel access shaft is located at the Kailua WWTP end of the proposed gravity tunnel. That is because diesel engine powered equipment, both fixed and mobile, will operate at the access shaft during tunneling operations. In addition, the necessity to ventilate the tunnel as it is being excavated will require the placement of noisy ventilation equipment at the Kailua WWTP end of the tunnel. Potential vibration impacts during tunneling operations are possible during excavation of the gravity tunnel at relatively short distances from the building structures which are above or to the side of the tunnel. In addition, noise and vibration impacts are possible during blasting operations at the Kailua WWTP end of the gravity tunnel. Risks of damage to the building structures as well as annoyance to the building occupants were evaluated during construction along the proposed gravity tunnel alignment.

As is the situation with all large construction projects, it will not be practical to reduce construction noise to inaudible levels. It will not be feasible to eliminate all noise impacts during construction of the project. But because of the relatively long period of actual construction activities and the relatively low levels of background noise in the surrounding area, special construction noise mitigation measures are recommended. These measures include: sound attenuation treatment of fixed machinery which operate continuously so as to limit their combined maximum noise levels to 65 dBA at the closest residences during the daytime and to 45 dBA at the closest residences during the nighttime; selection of the tunnel alignment which maximizes the distances to noise sensitive structures; requiring the use of broadband back-up alarms for vehicles which operate on the construction sites in place of the more commonly used high frequency, beeper back-up alarms; consideration of the use of HECO service drops if necessary to meet the project noise limits during the daytime or nighttime periods; and investigation of the feasibility of using an alternate heavy truck route for transporting spoils and materials to and from the Kaneohe WWPS construction site.



PROJECT LOCATION MAP AND NOISE MEASUREMENT LOCATIONS

FIGURE 1

CHAPTER II. PURPOSE

The primary objective of this study was to describe the existing and potential noise environment in the environs of the proposed Kaneohe / Kailua Wastewater Gravity Tunnel Alternative project on the windward side of the island of Oahu. This study was limited to evaluations of the noise and vibration impacts during construction. The potential noise impacts were examined at the tunnel access shafts, and the potential vibration impacts were evaluated at locations where relatively short distances were expected between the gravity tunnel and existing residences. One specific objective was to estimate potential construction equipment noise levels associated with the construction of the gravity tunnel between the Kaneohe WWPS and the Kailua WWTP, and to describe the potential noise impacts in the residential areas in the immediate vicinity of the project. The second specific objective was to estimate potential ground vibration levels associated with the tunneling operations between the Kaneohe WWPS and the Kailua WWTP, and to describe the potential vibration impacts in the residential areas which are near the alignment of the proposed gravity tunnel.

Recommendations for minimizing potential construction noise and vibration impacts were also to be provided as required.

CHAPTER III. NOISE DESCRIPTORS AND THEIR RELATIONSHIP TO LAND USE COMPATIBILITY

The noise descriptor currently used by federal agencies (such as FHA/HUD) to assess environmental noise is the Day-Night Average Sound Level (DNL). This descriptor incorporates a 24-hour average of instantaneous A-Weighted Sound Levels as read on a standard Sound Level Meter. By definition, the minimum averaging period for the DNL descriptor is 24 hours. Additionally, sound levels which occur during the nighttime hours of 10:00 PM to 7:00 AM are increased by 10 decibels (dB) prior to computing the 24-hour average by the DNL descriptor. A more complete list of noise descriptors is provided in APPENDIX B to this report.

TABLE 1, derived from Reference 1, presents current federal noise standards and acceptability criteria for residential land uses. TABLE 2, also extracted from Reference 1, presents the general effects of noise on people in residential use situations. Land use compatibility guidelines for various levels of environmental noise as measured by the DNL descriptor system are shown in FIGURE 2 (from Reference 2). As a general rule, noise levels of 55 DNL or less occur in rural areas, or in areas which are removed from high volume roadways. In urbanized areas which are shielded from high volume streets, DNL levels generally range from 55 to 65 DNL, and are usually controlled by motor vehicle traffic noise. Residences which front major roadways are generally exposed to levels of 65 DNL, and as high as 75 DNL when the roadway is a high speed freeway. In the project area immediately adjacent to Kaneohe Bay or away from the main roadways, traffic noise levels (as well as background noise levels) tend to be very low, and are at or less than 55 DNL.

For purposes of determining noise acceptability for funding assistance from federal agencies (FHA/HUD and VA), an exterior noise level of 65 DNL or less is considered acceptable for residences. This standard is applied nationally (Reference 3), including Hawaii. Because of our open-living conditions, the predominant use of naturally ventilated dwellings, and the relatively low exterior-to-interior sound attenuation afforded by these naturally ventilated structures, an exterior noise level of 65 DNL does not eliminate all risks of noise impacts. Because of these factors, and as recommended in Reference 4, a lower level of 55 DNL is considered as the "Unconditionally Acceptable" (or "Near-Zero Risk") level of exterior noise. However, after considering the cost and feasibility of applying the lower level of 55 DNL, government agencies such as FHA/HUD and VA have selected 65 DNL as a more appropriate regulatory standard.

For commercial, industrial, and other non-noise sensitive land uses, exterior noise levels as high as 75 DNL are generally considered acceptable. Exceptions to this occur when naturally ventilated office and other commercial establishments are exposed to exterior levels which exceed 65 DNL.

On the island of Oahu, the State Department of Health (DOH) regulates noise from construction activities through the issuance of permits for allowing excessive

TABLE 1

EXTERIOR NOISE EXPOSURE CLASSIFICATION (RESIDENTIAL LAND USE)

NOISE EXPOSURE CLASS	DAY-NIGHT SOUND LEVEL	EQUIVALENT SOUND LEVEL	FEDERAL (1) STANDARD
Minimal Exposure	Not Exceeding 55 DNL	Not Exceeding 55 Leq	Unconditionally Acceptable
Moderate Exposure	Above 55 DNL But Not Above 65 DNL	Above 55 Leq But Not Above 65 Leq	Acceptable(2)
Significant Exposure	Above 65 DNL But Not Above 75 DNL	Above 65 Leq But Not Above 75 Leq	Normally Unacceptable
Severe Exposure	Above 75 DNL	Above 75 Leq	Unacceptable

Notes: (1) Federal Housing Administration, Veterans Administration, Department of Defense, and Department of Transportation.

(2) FHWA uses the Leq instead of the Ldn descriptor. For planning purposes, both are equivalent if: (a) heavy trucks do not exceed 10 percent of total traffic flow in vehicles per 24 hours, and (b) traffic between 10:00 PM and 7:00 AM does not exceed 15 percent of average daily traffic flow in vehicles per 24 hours. The noise mitigation threshold used by FHWA for residences is 67 Leq.

TABLE 2

EFFECTS OF NOISE ON PEOPLE (Residential Land Uses Only)

EFFECTS[1] / DAY-NIGHT AVERAGE SOUND LEVEL IN DECIBELS	Hearing Loss	Speech Interference		Annoyance[2]	Average Community Reaction[4]	General Community Attitude Towards Area
		Indoor	Outdoor			
	Qualitative Description	%Sentence Intelligibility	Distance in Meters for 95% Sentence Intelligibility	% of Population Highly Annoyed[3]		
75 and above	May Begin to Occur	98%	0.5	37%	Very Severe	Noise is likely to be the most important of all adverse aspects of the community environment.
70	Will Not Likely Occur	99%	0.9	25%	Severe	Noise is one of the most important adverse aspects of the community environment.
65	Will Not Occur	100%	1.5	15%	Significant	Noise is one of the important adverse aspects of the community environment.
60	Will Not Occur	100%	2.0	9%	Moderate to Slight	Noise may be considered an adverse aspect of the community environment.
55 and below	Will Not Occur	100%	3.5	4%		Noise considered no more important than various other environmental factors.

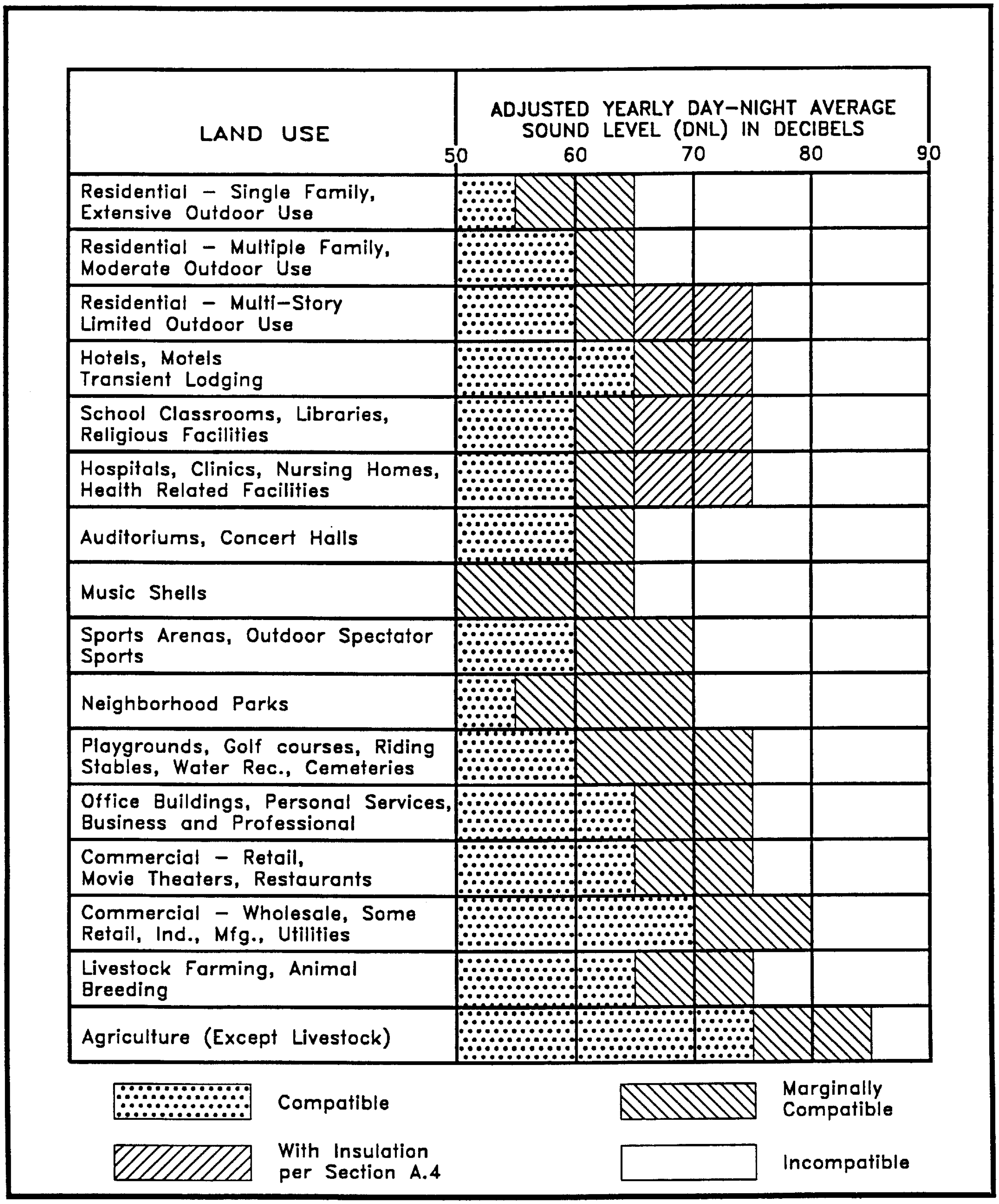
1. "Speech Interference" data are drawn from the following tables in EPA's "Levels Document": Table 3, Fig. D-1, Fig. D-2, Fig. D-3. All other data from National Academy of Science 1977 report "Guidelines for Preparing Environmental Impact Statements on Noise, Report of Working Group 69 on Evaluation of Environmental Impact of Noise."

2. Depends on attitudes and other factors.

3. The percentages of people reporting annoyance to lesser extents are higher in each case. An unknown small percentage of people will report being "highly annoyed" even in the quietest surroundings. One reason is the difficulty all people have in integrating annoyance over a very long time.

4. Attitudes or other non-acoustic factors can modify this. Noise at low levels can still be an important problem, particularly when it intrudes into a quiet environment.

NOTE: Research implicates noise as a factor producing stress-related health effects such as heart disease, high-blood pressure and stroke, ulcers and other digestive disorders. The relationships between noise and these effects, however, have not as yet been quantified.



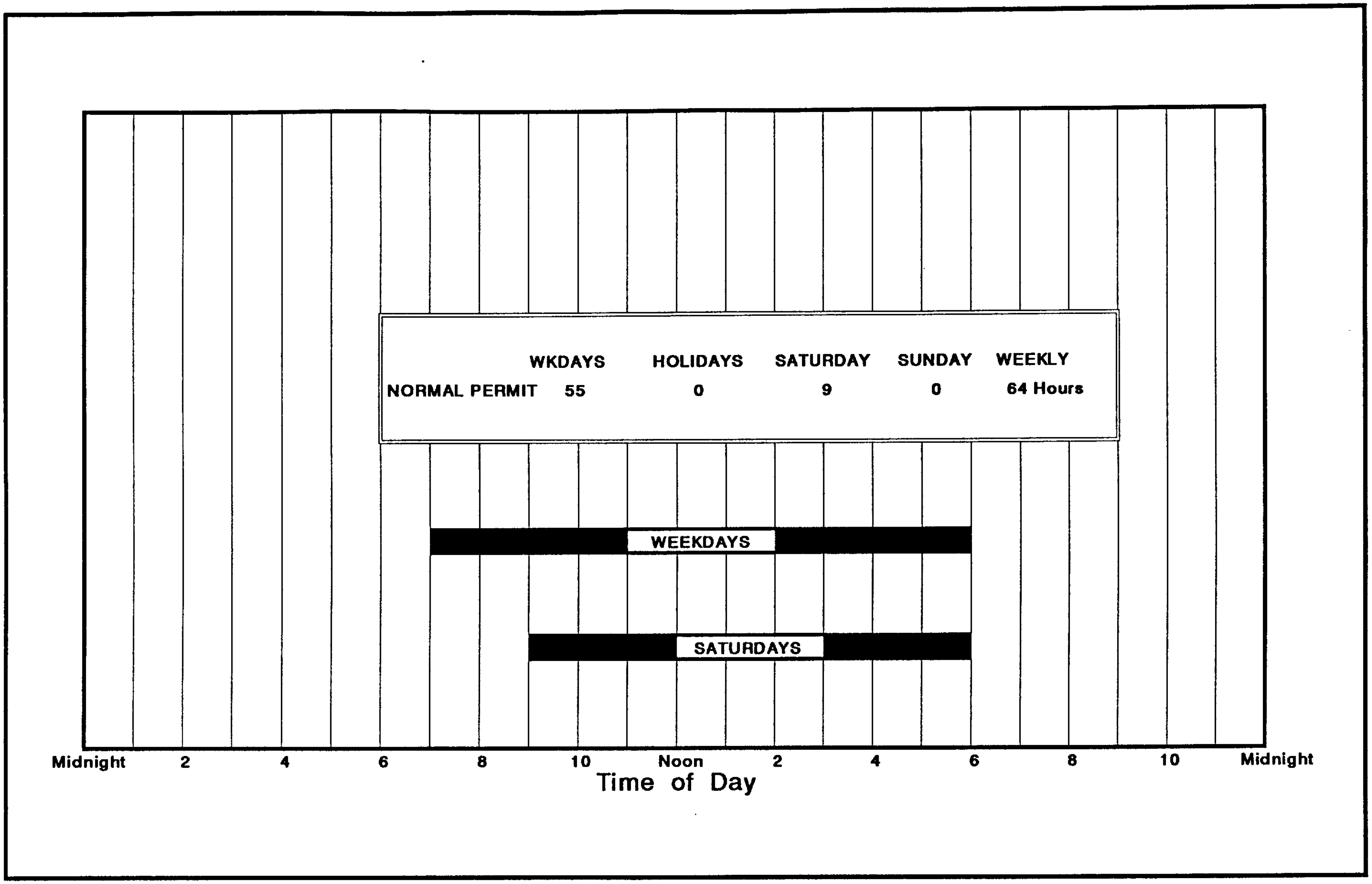
LAND USE COMPATIBILITY WITH YEARLY AVERAGE DAY–NIGHT AVERAGE SOUND LEVEL (DNL) AT A SITE FOR BUILDINGS AS COMMONLY CONSTRUCTED.
(Source: American National Standards Institute S12.9–1998/Part 5)

FIGURE 2

noise during limited time periods. The limited time periods normally permitted are the daytime hours on weekdays and Saturdays, with noisy construction activities not permitted on Sundays and holidays (see FIGURE 3). State DOH noise regulations are expressed in maximum allowable property line noise limits rather than DNL (see Reference 5). Although they are not directly comparable to noise criteria expressed in DNL, State DOH noise limits for residential, commercial, and industrial lands equate to approximately 55, 60, and 76 DNL, respectively.

It should be noted that the noise compatibility guidelines and relationships to the DNL noise descriptor may not be applicable to impulsive noise sources. The use of penalty factors (such as adding 10 dB to measured sound levels or the use of C-Weighting filters) have been proposed. However, the relationships between levels of impulsive noise sources and land use compatibility have not been as firmly established as have the relationships for nonimpulsive sources. The State DOH limits for impulsive sounds which exceed 120 impulses in any 20 minute period are 10 dB above the limits for non-impulsive sounds. If impulsive sounds do not exceed 120 impulses in any 20 minute time period, there are no regulatory limits on their sound levels under the State DOH regulations.

Where construction work is required during the evening or nighttime hours, or on Sundays or holidays, the granting of a noise variance is possible from the State DOH whenever the broader public interests are served by the variance. Examples of construction activities where noise variances have been granted for work during the nighttime, Sunday, or holiday periods are: highway repaving and reconstruction, work on bridges which cross over highways, sewer line rehabilitation, sewer manhole rehabilitation, water line rehabilitation, and electrical facility repairs and installation. In general, construction work is performed during the evening or nighttime hours, or on Sundays or holidays because of less traffic congestion during those periods, the economic impacts on property owners along the project corridor, or because of the need to perform certain types of specialized construction work (cured-in-place pipe lining, or high voltage cable splicing) around-the-clock.



AVAILABLE WORK HOURS UNDER DOH PERMIT PROCEDURES FOR CONSTRUCTION NOISE

FIGURE 3

CHAPTER IV. GENERAL STUDY METHODOLOGY

Reference 6 was used to identify the proposed gravity tunnel alternative for wastewater conveyance between the Kaneohe Wastewater Pump Station (WWPS) and the Kailua Wastewater Treatment Plant (WWTP). The proposed gravity tunnel alignment, locations of tunnel access shafts at each end of the gravity tunnel, and the location of a potential service access shaft were identified in Reference 6. Excavation of the shafts and tunnel will probably involve the use of blasting and the use of a Tunnel Boring Machine (TBM) with conveyor in addition to standard excavation methods using excavators and loaders. The potential noise and vibration impacts associated with these various construction methods were evaluated, and possible mitigation measures identified.

Existing evening, nighttime, and early morning background noise levels were measured at five locations (B, C, D, E, and F) in the project environs to provide a basis for describing the existing background noise levels at noise sensitive receptors in the project environs. The locations of the measurement sites are shown in FIGURE 1. Noise measurements were performed during the months of December 2008 and October 2009. The results of the background noise measurements were compared with calculations of predicted noise levels during construction activities which may occur during the project.

More emphasis was placed on describing the nighttime noise levels in the project environs, because of the probable need to perform some phases of construction during the nighttime hours. During the daytime hours between 7:00 am and 6:00 pm on weekdays (excluding holidays), and between 9:00 am to 6:00 pm on Saturdays, construction activities are normally permitted under the State DOH noise regulations (see FIGURE 3). Mitigation of construction noise during those normally permitted periods are less critical to the progress of the work, because they tend to occur during the daytime hours when most residents are awake. During the nighttime period, when most residents are asleep, there are increased risks of annoyance and sleep interference when construction occurs during the night. If the noise from construction activities does not exceed normal background noise levels, risks of adverse noise impacts from the construction activities will tend to be much lower than if the construction noise was much higher than the normal background noise levels.

For this project, the State DOH noise limits of 55 dBA during the daytime (7:00 am to 10:00 pm) and 45 dBA during the nighttime (10:00 pm to 7:00 am) were also used as the minimum thresholds for evaluating potential noise impacts. As shown in FIGURE 1, essentially all of the developed lands in the Kaneohe Bay environs are zoned for single family residential or preservation uses. So these daytime and nighttime noise thresholds are consistent with the property line limits of Reference 5. It should be noted that these thresholds are being used only for the purposes of this study, since the State DOH typically applies these noise limits only to fixed machinery, and not to other mobile or portable noise sources which are used in construction, and which are regulated using the DOH construction noise permitting process.

In addition to the State DOH 55 dBA and 45 dBA noise limits for single family residential and preservation uses, the FHA/HUD noise standard of 65 DNL was also used to evaluate potential noise impacts from heavy truck traffic to and from the Kaneohe WWPS and Kailua WWTP construction sites. The 65 DNL standard was also used to establish the recommended noise limits for construction noise from fixed machinery and equipment at the closest residences to the construction sites.

The potential noise levels at residences closest to the shafts at the Kaneohe and Kailua ends of the gravity tunnel during construction of the gravity tunnel were estimated in order to evaluate the potential noise impacts which may occur during construction. It is expected that most of the work will be performed during the normally permitted daytime hours on weekdays and Saturdays. However, the operation of the TBM for 24 hours per day may also occur, particularly if the likelihood of adverse noise and vibration impacts are very low. Therefore, potential noise and vibration impacts at the closest affected residences were also evaluated.

Recommendations for mitigating potential noise and vibration impacts were also provided for construction activities during the normally permitted daytime construction period as well as for construction activities which would be required during the nighttime, holiday, or Sunday construction periods.

V. EXISTING ACOUSTICAL ENVIRONMENT

Because the coastline of Kaneohe Bay is removed from the major roadways (Kaneohe Bay Drive, H-3 Freeway, and Kamehameha Highway), the existing background ambient noise levels along the coastline are relatively low and controlled by the sounds of natural and human activities, and distant traffic and local traffic on roadways in the project area. The natural sounds could include the sound of surf, birds, animals, insects, and foilage moving with the wind. The sounds of human activities could include lawn mowers, leaf blowers, music, home construction, and conversations. Background noise levels during the daytime tend to be higher with intermittent excursions to the 60 or 80 dBA level during intermittent noise events, while background noise levels during the nighttime tend to be lower and drop to levels below 30 dBA during the quietist periods. Background noise levels along the coastline of Kaneohe Bay tend to be lower than those in the developed inland areas, due to local and distant traffic noise.

TABLE 3 presents the results of the nighttime background noise measurements at Locations B and D through F. FIGURE 4 is a strip chart of background noise levels continuously recorded at Location C in December 2008. The measurement results indicate that residents along the shoreline of Kaneohe Bay (as well as those in the mauka lands) probably experience relatively low levels of background noise during the nighttime period, particularly when they are located away from or are shielded from the major roadways. Existing average background noise levels during the daytime hours are probably in the range of 55 to 60 dBA, and existing average background noise levels during the nighttime hours are probably in the range of 35 to 45 dBA, and are probably similar to the State DOH property line noise limits of 55 dBA and 45 dBA for the daytime and nighttime periods, respectively.

Along the major roadways in the project area, such as Kaneohe Bay Drive, existing background noise levels are controlled by traffic noise. At approximately 50 feet from the centerline of Kaneohe Bay Drive, traffic noise levels range from 72 to 86 dBA during motor vehicle passbys, with average noise levels ranging from 56 to 66 dBA. Traffic noise levels tend to be highest at the first row of dwellings which front the roadway, and diminish at dwellings which are further removed from the roadway or which are shielded by the terrain and structures which block the visual line of sight between the dwelling and roadway vehicles. Traffic noise levels tend to be highest during the daytime hours, increasing rapidly during the morning commuting period, remaining relatively constant during the daytime hours, increasing slightly during the afternoon commuting period, and decreasing during the evening and nighttime period to its lowest level at 3:30 to 4:30 am.

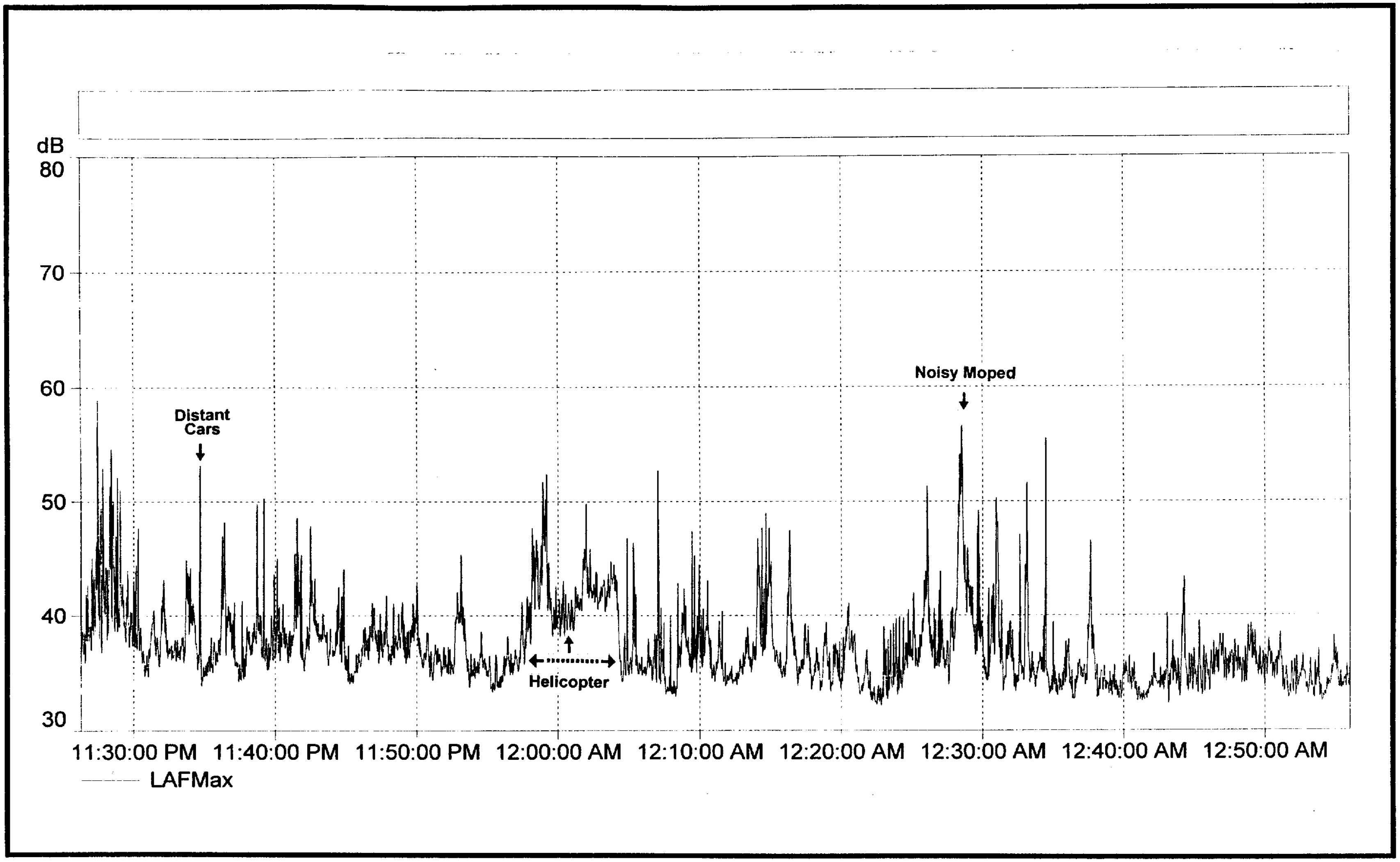
Existing background noise levels in the project environs are too low to mask the noise from typical construction activities, whether they involve open trenching or trenchless methods. So, as is typical in essentially all areas where construction activities occur, construction noise is typically audible, irrespective of the existing background noise levels. And in the project environs, where background noise levels

TABLE 3
SUMMARY OF MEASURED BACKGROUND NOISE LEVELS AT VARIOUS LOCATIONS

LOCATION: KANEOHE BAY FOR KANEOHE / KAILUA GRAVITY TUNNEL
DATE: October 22-23, 2009

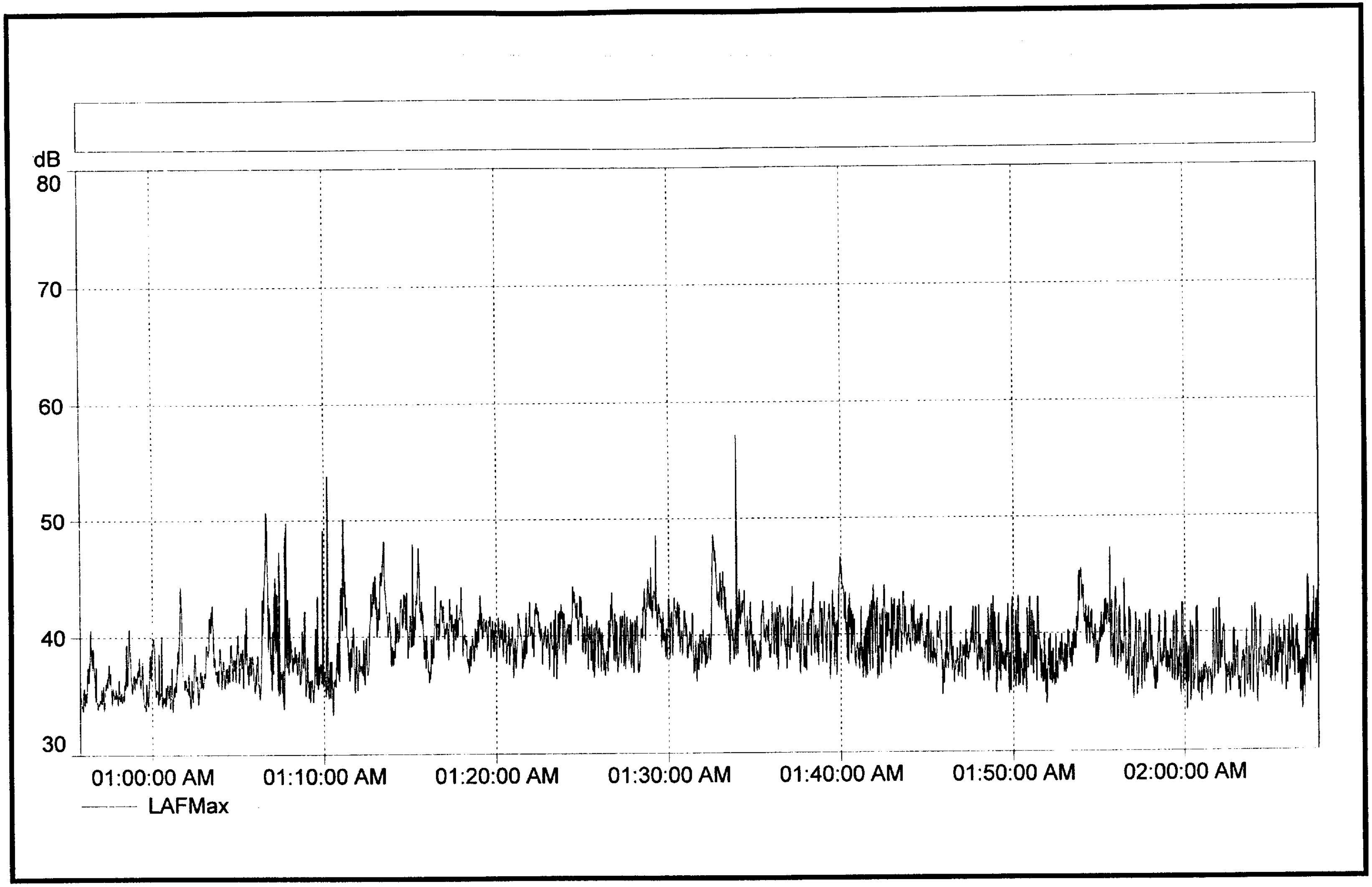
Start Time	End Time		Leq	Lmax	Lmin	L1	L10	L50	L90	L99	Event Description
Location "B" - Waikalua Road, Kaneohe Beach Park											
1924	1939		48.7	68.6	43.3	56.8	51.5	46.7	44.7	43.5	
2121	2136		45.6	70.9	39.8	52.6	47.6	44.4	42.1	40.4	
2322	2337		35.9	57.1	31.9	42.0	37.3	34.7	33.2	32.3	
0134	0150		40.4	58.4	34.7	46.5	43.1	39.6	36.6	34.6	
0332	0347		37.1	68.3	29.6	42.7	38.2	34.2	31.5	30.0	
Location "D" - Likeke Place											
1950	2005		54.7	71.3	41.9	60.7	57.0	53.6	50.7	43.8	Loud Music from Nearby Home
2056	2111		55.9	65.9	40.9	60.3	58.0	55.7	52.9	47.0	Loud Music from Nearby Home
											Intermittent Weak Music
0108	0123		41.9	53.7	39.8	46.3	43.3	41.4	40.6	40.0	Music Not Audible
0308	0323		36.3	55.2	31.7	44.0	38.6	34.1	32.5	32.0	
Location "E" - Paku Place											
2035	2050		45.8	61.1	39.6	54.8	48.3	43.9	42.2	41.2	
2234	2249		46.8	71.9	40.0	57.7	46.4	45.0	44.1	40.4	
0046	0101		38.1	62.8	33.9	44.5	39.9	36.8	34.8	34.2	
0247	0302		39.0	54.3	37.2	42.7	40.1	38.6	37.9	37.1	
Location "F" - Aikahi Gardens											
2016	2031		56.3	71.8	40.4	64.8	60.6	52.1	44.3	42.0	
2215	2230		55.1	73.9	37.6	64.9	59.7	49.1	41.0	38.6	
0019	0034		50.1	71.1	34.6	64.0	51.2	38.4	36.1	35.2	
0228	0243		49.7	71.0	32.7	64.0	49.6	38.1	35.2	33.8	

Notes:
a. Leq = Average A-Weighted Sound Level (in dBA)
b. Lmax = Maximum A-Weighted Sound Level (in dBA)
c. Lmin = Minimum A-Weighted Sound Level (in dBA)
d. L10 = A-Weighted Sound Level (in dBA) which was exceeded 10 percent of the time.
e. Lxx = A-Weighted Sound Level (in dBA) which was exceeded xx percent of the time.



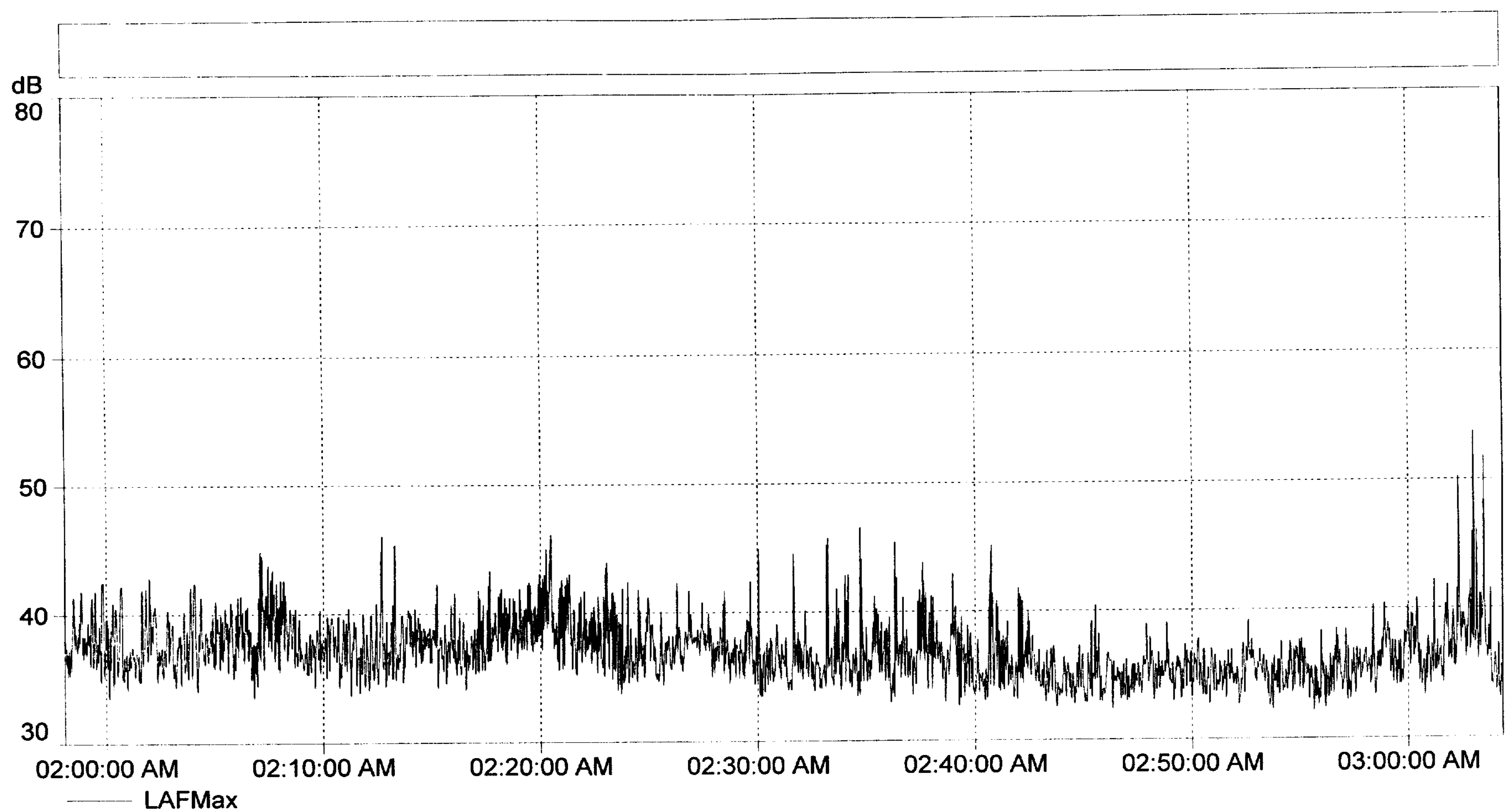
MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION " C "

FIGURE 4



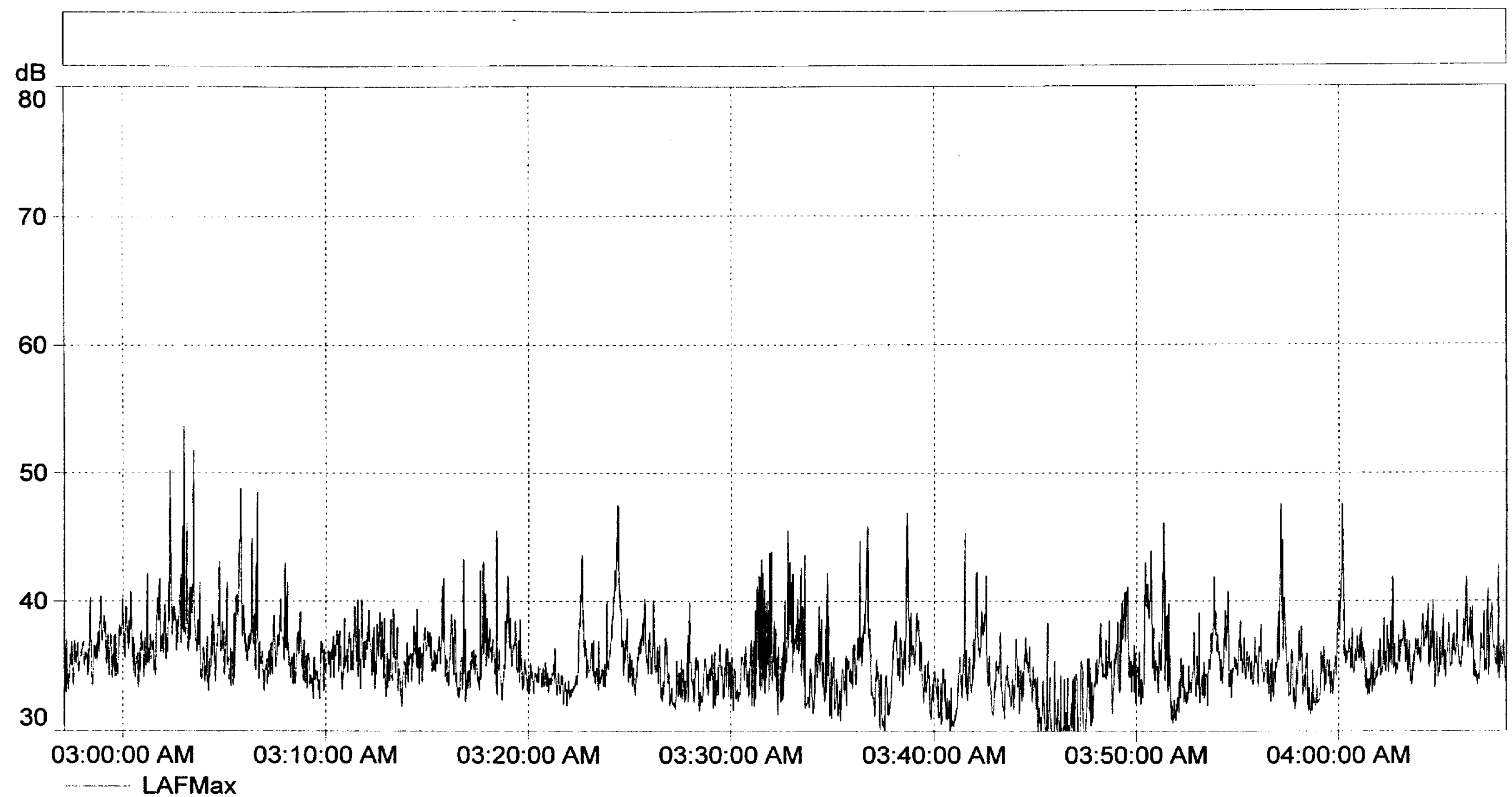
MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION " C "

FIGURE 4(CONT.)



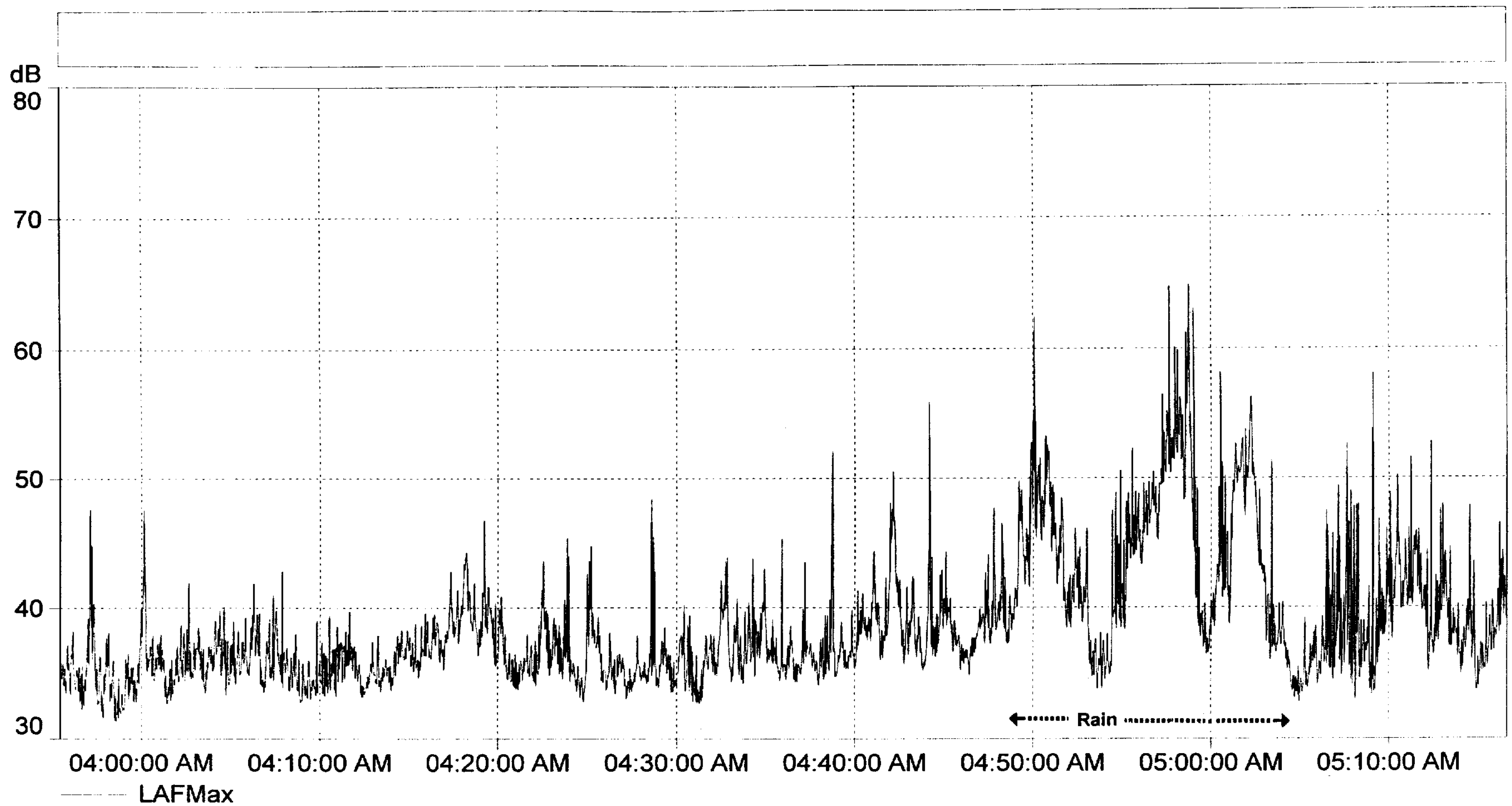
MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION " C "

FIGURE 4(CONT.)



MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION " C "

FIGURE 4(CONT.)



MEASURED NIGHTTIME BACKGROUND NOISE LEVELS (IN dBA) AT LOCATION " C "

FIGURE 4(CONT.)

are more typical of rural rather than densely populated areas, construction activities will tend to be audible at longer distances from the locations of the construction equipment.

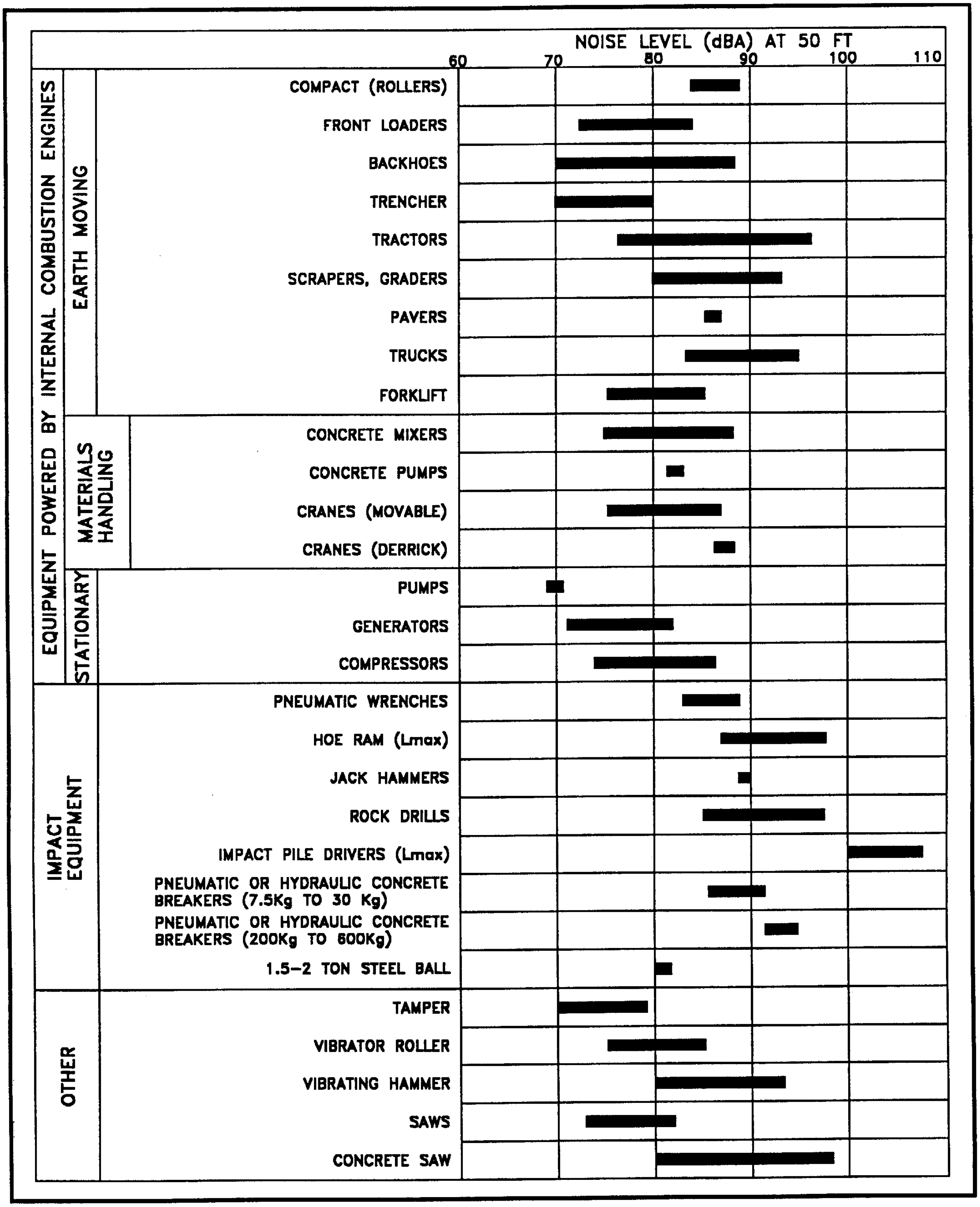
CHAPTER VI. DESCRIPTION OF POTENTIAL FUTURE NOISE LEVELS

General. The potential future noise and vibration levels associated with the implementation of the Kaneohe / Kailua Gravity Tunnel using a trenchless construction method are essentially all associated with the activities which could occur during the construction of the gravity tunnel. Although the trenchless method using a TBM primarily involve the construction of a tunnel under the lands mauka of Kaneohe Bay, construction work above ground will also be required in excavating access shafts on shore at the Kaneohe WWPS and Kailua WWTP ends, as well as near the mid-point of the gravity tunnel. In addition, the trucking of spoils from the Kaneohe and Kailua ends of the gravity tunnel to a disposal location in Waianae or another storage site on Oahu will be required.

In constructing the gravity tunnel, a Tunnel Boring Machine (TBM) is expected to be launched from the Kailua WWTP end of the tunnel following excavation of the access shaft. Blasting is expected to be used during excavation of the access shaft as well as the initial portion of the tunnel. The TBM is expected to be powered by commercial electrical power, and will be supported with a material conveyor, ventilation fan, and materials handling equipment operating near the Kailua access shaft. Trucking of the excavated materials from the onsite storage locations at the Kailua WWTP to offsite locations will occur primarily during the normal working hours. During the tunnel excavation phase, an average of 60 trucks per day will be entering and 60 trucks per day will be leaving the Kailua WWTP while transporting excavated materials. The TBM may operate around the clock (24 hours per day) unless adverse noise or vibration impacts preclude such operations.

At the Kaneohe WWTP end of the gravity tunnel, a tunnel access shaft will be excavated using conventional methods, and the excavated materials will be trucked from the Kaneohe WWPS to a disposal location in Waianae or another storage site on Oahu. It is anticipated that construction operations will be limited to the normally permitted periods during construction of the access shaft and during recovery of the TBM.

Typical noise levels of construction equipment are shown in FIGURE 5 and TABLE 4. The decrease in construction equipment noise with increasing distance from the noisier equipment is shown in FIGURE 6. The primary locations where these equipment noise sources may be operating are in the vicinity of the tunnel access shafts at the two ends and midpoint of the gravity tunnel. Because the available setback distances between the residences and the construction equipment are relatively small at the Kaneohe and Kailua ends of the gravity tunnel, relatively high noise levels during construction may be unavoidable, particularly during operations of mobile equipment such as trenchers, loaders, diesel trucks, backhoes, vacuum trucks, and cranes. Fortunately, these mobile equipment tend to operate over shorter intervals of time rather than continuously. The equipment which tend to operate continuously, such as generators, pumps, ventilation fans, etc., are typically fixed at specific locations on the construction site, could be fitted with sound attenuation treatment (barriers,



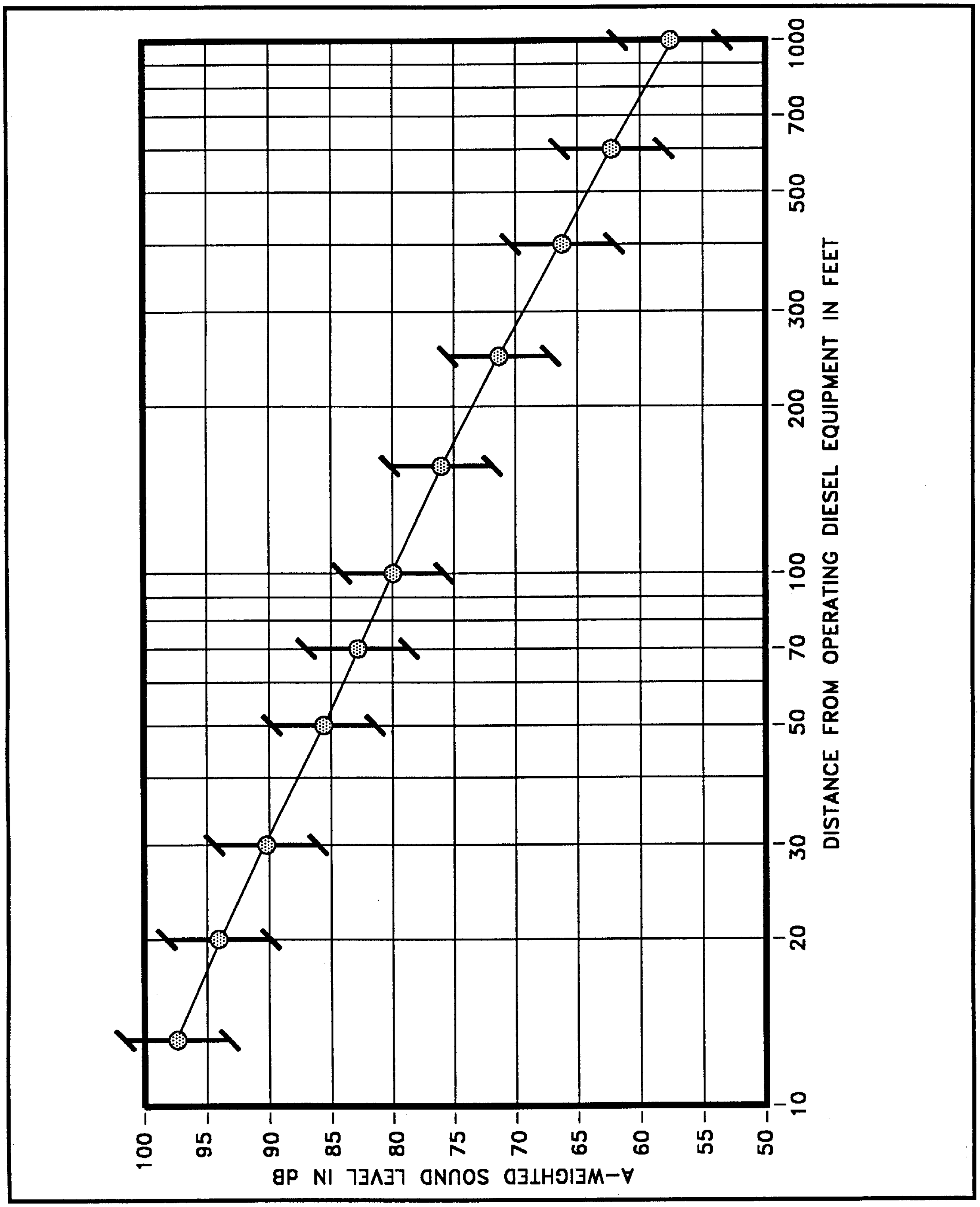
RANGES OF CONSTRUCTION EQUIPMENT NOISE LEVELS

FIGURE 5

TABLE 4

RANGES OF A-WEIGHTED SOUND LEVELS OF CONSTRUCTION EQUIPMENT AT 50 FOOT DISTANCE

EQUIPMENT	SOUND LEVELS (dBA) (Minimum / Maximum)
Excavator	70 / 90
Backhoe	72 / 85
Forklift / Loader	72 / 85
25 Ton Crane	75 / 87
225 KW Generator	67
Trash Pump	70 / 80
Vacuum Truck	72 / 85
80 Ton KRUPP Crane (Quiet)	62 / 73
40 Ton KRUPP Crane	73 / 83
Ventilation Fan	70 / 70
Beeper Type Back Up Alarm	86 / 91
Broadband Back Up Alarm	86 / 89



ANTICIPATED RANGE OF CONSTRUCTION NOISE LEVELS VS. DISTANCE

FIGURE 6

enclosures, silencers, etc.), and will typically have lower noise levels than those associated with the mobile construction equipment.

At the Kailua WWTP end of the gravity tunnel where the TBM is expected to be launched, the economic incentive for operating the TBM continuously and around the clock will probably result in a need to quiet the fixed machinery (ventilating fans, conveyors, pumps, etc.) which support the TBM operations to 45 dBA at the mauka and makai property lines of Kailua WWTP which face existing residential developments. Unlike other construction operations which typically occur during the daytime hours, and which may include short term periods of nighttime activity to minimize traffic congestion, the tunnel excavation activities at the Kailua WWTP end are expected to exceed 7 months if 24 hour operations are allowed. Because it will be difficult for the neighboring residences to adjust to recurring and daily nighttime noise disturbances over a prolonged period, it is unlikely that excessively noisy construction activities would be allowed during the nighttime periods. Therefore, noise mitigation measures which are designed to comply with the State DOH nighttime noise limit of 45 dBA at the Kailua WWTP property boundaries with face residences will be required. If noise barriers are erected around the entire construction site to comply with the 45 dBA limit for fixed noise sources, it is expected that the noise levels of mobile equipment will also be attenuated during their operation within the area surrounded by the noise barriers.

At the Kaneohe WWPS end of the gravity tunnel where the TBM is expected to be recovered, construction activities will probably be limited to the normally permitted daytime periods shown in FIGURE 3. Therefore, noise levels during construction at the tunnel access shaft are expected to be similar to those shown in FIGURE 6, be similar to other heavy construction activities in Hawaii, and range between 80 to 90 dBA at 50 feet distance from the operating equipment. Those residences which are within direct lines-of-sight and which are closest to the construction equipment will tend to experience the highest noise levels as indicated in FIGURE 6.

<u>Spoils Transporting Truck Operations</u>. Materials (or spoils) excavated from tunnel access shaft at the Kaneohe end of the gravity tunnel will need to be transported to a landfill site in Waianae or another storage site on Oahu using dump trucks at a maximum frequency of 4 loads per hour from Kaneohe WWPS. The maximum noise level during the truck passby may be as high as 90 dBA at 50 feet and 94 dBA at 25 feet distance from the roadway centerline. At a total of 8 (4 inbound plus 4 outbound) heavy truck trips per hour, the average hourly noise level from the truck trips could be as high as 61 Leq(h) at 50 feet, and 65 Leq(h) at 25 feet from the roadway centerline. Assuming that this rate of heavy truck traffic is maintained for 10 hours per day, the average DNL value of the truck noise is predicted to range between 57 DNL at 50 feet to 61 DNL at 25 feet from the roadway centerline.

The heavy truck route between Kaneohe Bay Drive and the Kaneohe WWPS may be along Puohala and Kulauli Streets, which passes through residential areas. This situation is considered to have the worst case potential for adverse noise impacts from heavy truck traffic due to the relatively short setback distances to the residences and because of the relatively lower levels of existing traffic and background noise along these two streets. The typical setback distances from the centerlines of these streets to the residences range from approximately 35 to 55 feet. Therefore, predicted noise levels during a 10 hour materials hauling day from the heavy truck traffic could range from 57 to 59 DNL. These levels are below the FHA/HUD noise standard of 65 DNL for residences, and should be below the federally accepted threshold for adverse noise impact.

The heavy truck route to and from the Kailua WWTP will probably be along Kaneohe Bay Drive to and from Mokapu Boulevard. During a 10 hour work day, a maximum of 200 heavy truck passbys along the truck route could occur during the tunnel excavation phase. For an hourly total of 20 heavy truck passbys, and at 90 dBA at 50 feet from a truck passby, the predicted hourly (or average) noise level due to the project's heavy truck traffic is 67 Leq(h). This level is probably comparable to the existing traffic noise levels along Kaneohe Bay Drive and Mokapu Boulevard, and is well below the FHA/HUD noise standard of 65 DNL for residences. Assuming that this rate of 20 heavy truck passbys is maintained for 10 hours per day, the average DNL value of the truck noise is predicted to be 63 DNL at 50 feet. This level is below the FHA/HUD noise standard of 65 DNL for residences, and should be below the federally accepted threshold for adverse noise impact.

CHAPTER VII. DISCUSSION OF PROJECT-RELATED NOISE IMPACTS AND POSSIBLE MITIGATION MEASURES

General Construction Noise. Audible construction noise will probably be unavoidable during the entire project construction period. The total time period for actual construction is estimated to be approximately three years, with most of the work at the Kaneohe WWPS being performed during the normally permitted hours of 7:00 am to 6:00 pm on weekdays, and between 9:00 am to 6:00 pm on Saturdays. Typical levels of exterior noise from construction activities located near the Kaneohe WWPS access shaft are expected to range between 50 and 70 dBA at the closest residential receptors. Construction noise levels will probably be audible at the closest residences, and will exceed existing daytime background noise levels by 10 to 25 dBA. Typical levels of construction noise inside naturally ventilated and air conditioned structures are approximately 10 and 20 dBA less, respectively, than the 50 to 70 dBA values expected at the closest residences to the Kaneohe WWPS end of the gravity tunnel.

Mitigation of construction noise to inaudible levels will not be practical in all cases due to the intensity of construction noise sources (80 to 90+ dBA at 50 FT distance), and due to the exterior nature of the work (excavating, grading and earth and spoils moving, trenching, crane operations, hammering, etc.). The use of properly muffled construction equipment should be required on the job site. The anticipated noise levels during actual construction activities are typical of other construction activities (exterior earthwork, open trenching, or building erection).

At the Kailua WWTP end of the gravity tunnel, 24-hour operation of the TBM is desired. Because of this requirement, attenuation of the noise from equipment to be operating continuously or during the nighttime and curfew periods will be probably be required due to the relatively long duration (7 to 14 months) of the tunnel excavation period. The use of sound attenuating walls around the tunnel access shaft as well as the addition of special attenuating treatments to the noisy equipment will probably be required to reduce construction noise levels to the allowable nighttime limit of 45 dBA at the Kailua WWTP property boundary lines.

Possible Noise Mitigation Measures for General Construction Sources. Noise mitigation measures should be included in the Force Main No. 2 project if the gravity tunnel alternative is selected. The following noise mitigation measures are recommended for inclusion within the project construction documents:

1. Provide sound attenuation treatments (walls, enclosures, or silencers) to reduce all steady, continuous noise sources (generators, pumps, plants, fans, etc.) which operate during the normally permitted daytime hours so that they do not exceed 65 dBA at the closest residences.

2. For fixed or stationary equipment (generators, pumps, plants, fans, etc.) which need to operate 24 hours per day, provide sound attenuation treatments (walls,

enclosures, or silencers) to reduce their noise levels to the allowable State DOH limits of 45 or 50 dBA or less at the station boundaries with face residences.

3. Require the installation and use of broadband back-up alarms in place of beeper-type back-up alarms for all mobile equipment operating on the project work sites. The broadband alarms should be less audible at the longer distances, and should be less annoying at all distances from the mobile construction equipment. Use broadband alarms which automatically adjust the alarm sound level for differences in background noise level.

4. If prolonged periods of work are required during the non-permitted (or noise variance) hours, consider the use of HECO electrical service drops at the two ends of the gravity tunnel in place of portable generators and engine driven equipment (pumps, lights, etc.). These service drops may also be used to meet the 65 dBA maximum daytime level recommendation in Paragraph 1, and the 45 dBA nighttime level recommendation in Paragraph 2.

5. Investigate the feasibility of adding an alternate truck route between Kaneohe Bay Drive and the Kaneohe side construction site for spoils removal.

<u>Blasting Operations</u>. The use of blasting to break rock during excavation of the tunnel and access shaft at the Kailua WWTP end of the gravity tunnel alignment is planned. Distances from the tunnel access shaft to the closest residences are expected to be approximately 330 feet. Blast induced ground and air vibrations have the potential to startle or annoy surrounding residents, and to also cause damage to structures. However, when properly controlled, blasting operations at the proposed Kailua WWTP end of the gravity tunnel should not pose significant risks of damage or annoyance to neighboring buildings or residents.

<u>Airborne Noise from Blasting</u>. The air blasts associated with blasting are concussion type, low frequency vibrations, which are of relatively short duration (or impulsive) and generally described in terms of peak over pressure in psi, or in dBL. The dominant sources of the air blast are the Air Pressure Pulse, which is caused by the large displacement of the ground surface near the charge, and the Stemming Release Pulse, which is caused by gas pressure ejecting the stemming (fill) material from the hole bored for the explosive charge. The low frequency characteristic (usually referred to as bass sounds) of air blast noise tends to induce vibrations in structures (and subsequent complaint reactions) due to the low resonant frequency (10 to 25 Hz) of buildings. High frequency sounds of amplitudes equal to blast noise generally do not induce vibrations and cause physical damage to structures. Although the human ear has an opposite characteristic (i.e., the ear is less sensitive to low frequency sounds), structures which vibrate can produce secondary audible effects such as rattling sounds (of fixtures, doors, etc.), and effects which are sensitive to touch (or feelable). Sound levels at which these secondary effects occur vary with the weight (and probably stiffness) of the structure. In general, the inception point of sound induced vibration is difficult to establish, but may occur at levels as low as 80 dBL. These levels

are significantly below the peak levels of 120 to 136 dBL which have been associated with low risk of damage to structures.

If blasting is used to break rock, the charge weights per delay will be adjusted so as to eliminate any risk of damage to nearby structures. The levels of air blast are anticipated to be well below the structural damage criteria for buildings, so risks of window glass breakage from the blasting at the proposed project are considered to be very low. Since complaints resulting from air blast noise levels may occur at levels considerably below those necessary to cause damage to structures (120 to 136 dBL), additional analyses were conducted to estimate the percent of the neighboring population which may be highly annoyed by blasting operations. At air blast noise levels of 119 dBL, and with no more than two blasts per day, the average noise exposure levels from blasting operations are predicted to be 47 Lcdn, which is analogous to 47 DNL except for the use of C-Weighting rather than A-Weighting filters. An exposure level of 47 Lcdn (or 47 DNL) is very low, and less than 2 percent of the population exposed to this level are expected to be highly annoyed (see Reference 7). For these reasons, risks of adverse airborne noise impacts from blasting operations of up to two blasts per day, and which are also controlled to avoid risks of damage to structures are considered to be very low.

<u>Ground Vibration from Blasting</u>. Ground vibrations, or seismic waves, are also generated during blasting operations, and are generally described in terms of peak particle velocity in inches per second. Most of the seismic energy remains trapped in the ground, but some energy is released as an over pressure pulse into the air (or Rock Pressure Pulse). In general, the ground vibrations as well as the airborne Rock Pressure Pulse are expected to be less intrusive than the Air Pressure and Stemming Release Pulses. As an example, tunneling work along Dole Street on Oahu for a sewer project generated some initial air blast complaints from nearby residents during blasting of the surface entrance to the tunnel. However, once the entrance to the tunnel was formed and blasting was confined to tunneling underground, complaints stopped.

Predictions of peak over pressure or ground vibration levels vs. scaled distance from the blast are not precise, with initial uncertainties for a given location in the order of 20 to 30 dBL. For this reason, it is standard practice to employ seismograph monitoring of air and ground vibrations during blasting operations with a 3-axis geophone (for ground vibrations) and a microphone (for air vibrations).

The shortest separation distances between the potential blasting areas and surrounding noise sensitive neighbors range are relatively small and range from approximately 330 feet to approximately 120 feet. At these small separation distances between the blast areas and surrounding noise sensitive neighbors, charge weights may need to be limited to less than one pound of explosives per delay. At one pound of explosives per delay, the predicted vibration levels at 125 feet separation distance are in the order of 0.070 to 0.40 inches per second. These predicted levels of ground vibration are encroaching into the thresholds for structural or architectural damage to buildings, and may be feelable (see TABLE 5). In addition, these levels are also encroaching into the 0.35 inches per second threshold recommended to minimize adverse human responses to vibrations resulting from sporadic impulsive shock excitations (see Reference 8). Based on these predictions of vibration levels from blasting operations, it was concluded that risks of adverse impacts from ground vibrations can be very low, but the sizes of the charge weights per delay may need to be kept at relatively small values in order to minimize risks of damage to nearby structures.

Mitigation of Noise and Vibration Impacts from Blasting. Because blasts may be both feelable and audible in the surrounding communities, mitigation measures will probably be required to minimize risks of antagonizing nearby residents. These recommended mitigation measures are described as follows:

- Regularly monitor air blast and ground vibration levels simultaneously at the closest noise sensitive residence(s) or structure(s) during the blasting operations to develop the data base for the surrounding area.

- For initial blasts, prior to establishment of a data base of ground vibration and air blast levels vs. scaled distance, use the minimum practical charge weight (in equivalent pounds of TNT) per delay as well as the minimum practical number of delays (or bore holes).

- If practical, reduce maximum air blast levels to less than 110 dBL at the nearest noise sensitive residences in response to air blast complaints. Possible methods of accomplishing this are: reducing charge sizes; increasing delay intervals; increasing hole depth; orienting bore holes to direct the Stemming Release Pulse away from noise sensitive properties; trucking in high quality stemming material to minimize stemming blowouts; and filling (sandbagging) over the area to be blasted and the detonating chord.

- Schedule actual blasting during the warm periods of the day to minimize the possibility of thermal ducting and focusing of air blast noise at large distances from the blast. If possible, also schedule blasting during fixed time periods, so that the members of the community can also schedule their activities accordingly.

- The most conservative vibration criteria for damage to “ruins and ancient monuments” (see TABLE 5) is 0.15 inches per second. In order to address any resident’s concerns regarding the possible aggravation of ground settlement problems by the proposed blasting operations, it is recommended that additional study of the effects of low level vibrations on ground settlement be conducted. An attempt should be made to correlate locally measured vibration data from blasting or pile driving (at vibration levels which equal or exceed 0.05 inches per second and for various soil conditions) with any reported settlement problems in

TABLE 5

SUMMARY OF BUILDING DAMAGE CRITERIA

PEAK GROUND VELOCITY (mm/sec)	PEAK GROUND VELOCITY (in/sec)	COMMENT
193.04	7.6	Major damage to buildings (mean of data).
137.72	5.4	Minor damage to buildings (mean of data).
101.16	4.0	'Engineer structures' safe from damage.
50.8	2.0	Safe from damage limit (probability of damage <5%).
		No structural damage.
33.02	1.3	Threshold of risk of 'architectural' damage for houses.
25.4	1.0	No data showing damage to structures for vibration <1 in./sec.
15.24	0.6	No risk of 'architectural' damage to normal buildings.
10.16	0.4	Threshold of damage in older homes.
5.08	0.2	Statistically significant percentage of structures may experience minor damage (including earthquake, nuclear event, and blast data for old and new structures).
		No 'architectural' damage.
3.81	0.5 to 0.15	Upper limits for ruins and ancient monuments.
1.0	0.04	Vertical vibration clearly perceptible to humans.
0.32	0.01	Vertical vibration just perceptible to humans.

Source: 'State-of-the-Art Review: Prediction and Control of Groundborne Noise and Vibration from Rail Transit Trains'; U.S. Department of Transportation; December 1983.

nearby structures. The lack of any reported settlement problems in conjunction with a localized soils analysis for the area where the vibrations were measured should also be noted. The results of this additional study should then be used to select the applicable vibration criteria for areas with poor soil conditions.

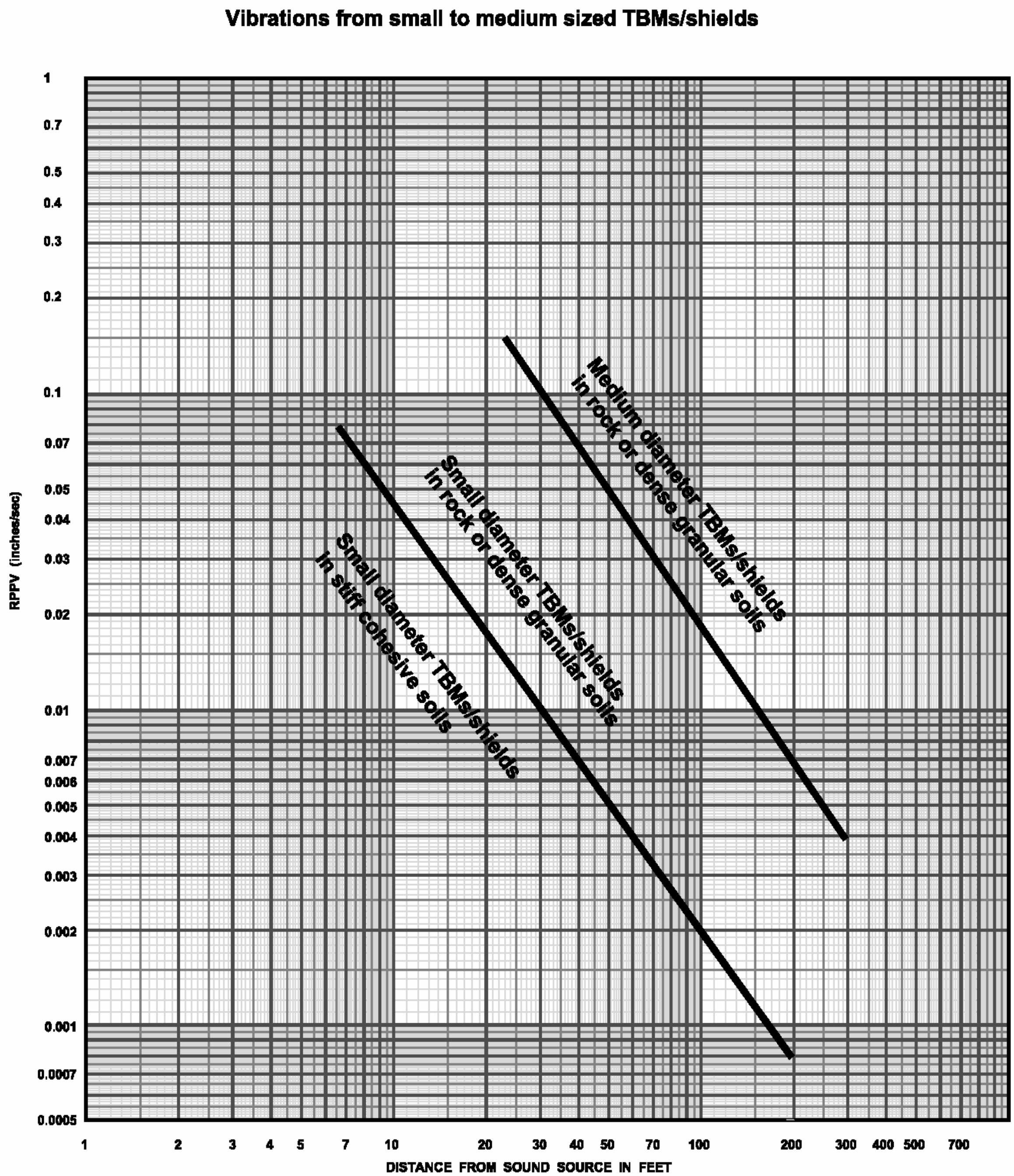
Ground Vibration from Tunnel Boring Machine. Ground vibrations from the TBM may be feelable whenever the TBM is relatively close to inhabited buildings. FIGURE 7 was constructed using vibration data developed in Reference 9. In general, the greater the separation distance between the TBM and the receptor, the lower the ground vibration level during excavation of the gravity tunnel should be at the receptor. From the medium diameter TBM, ground vibration levels should be at or less than 0.01 inches per second at 150 feet separation distance between the TBM and the receptor. From TABLE 5, a vibration level at or less than 0.01 inches per second should be barely perceptible to human beings. This "feelable" level of 0.01 inches per second is much lower than the 0.15 inches per second shown in TABLE 5 as the most conservative vibration level for potential damage to "ruins and ancient monuments". Also from FIGURE 7, in order to reach this higher level of 0.15 inches per second, the separation distance needs to be reduced to approximately 25 feet. All separation distances between the TBM and the structures closest to the gravity tunnel should exceed 25 feet, so there should be a low risk of structural or architectural damage resulting from the vibrations of the TBM.

The TBM will cross under residences at the Aikahi Gardens at separation distances between 100 to 150 feet, and also cross under residences along Kaneohe Bay Drive at separation distances between 100 to 150 feet. At these separation distances, vibration levels from the TBM are predicted to range from 0.019 to 0.010 inches per second (from FIGURE 7). These relatively low vibration levels may be just perceptible to humans as indicated in TABLE 5, and are well below the levels associated with risk of damage to buildings. Because these levels may be perceptible to some residents, mitigation measures may be required during TBM operations within 150 feet of a residence.

Mitigation of Vibration Impacts During TBM Operations. Because vibration may be feelable during the relatively close operations of the TBM within 150 feet of residences, mitigation measures will probably be required to minimize risks of antagonizing nearby residents during those periods when the TBM operations occur within 100 to 150 feet of the closest residences. These recommended mitigation measures are described as follows:

- Minimize the number of very short (less than 100 feet) separation distances between residential structures and the TBM in order to minimize risks of complaints due to vibration during tunnel excavation operations.

- Regularly monitor ground vibration levels at the closest noise sensitive residence(s) or structure(s) as the TBM approaches the closest residence(s) to



VIBRATIONS FROM SMALL TO MEDIUM SIZED TBMS / SHIELDS

FIGURE 7

develop the vibration data base for the surrounding area. Based on these monitoring efforts, determine if vibration levels at or near the closet point of approach could exceed the feelable levels; and if so, advise the affected residents. If nighttime TBM operations are planned, advise the affected residents, and be prepared to discontinue nighttime operations at the request of any affected resident.

APPENDIX A. REFERENCES

(1) "Guidelines for Considering Noise in Land Use Planning and Control;" Federal Interagency Committee on Urban Noise; June 1980.

(2) American National Standard, "Sound Level Descriptors for Determination of Compatible Land Use," ANSI S12.9-1998/ Part 5; Acoustical Society of America.

(3) "Environmental Criteria and Standards, Noise Abatement and Control, 24 CFR, Part 51, Subpart B;" U.S. Department of Housing and Urban Development; July 12, 1979.

(4) "Information on Levels of Environmental Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety;" U.S. Environmental Protection Agency; EPA 550/9-74- 004; March 1974.

(5) "Title 11, Administrative Rules, Chapter 46, Community Noise Control;" Hawaii State Department of Health; September 23, 1996.

(6) "Environmental Assessment / Environmental Impact Statement Preparation Notice; Kaneohe / Kailua Wastewater Conveyance and Treatment Facilities;" Wilson Okamoto Corporation; June 2010.

(7) "Method for Assessment of High-Energy Impulsive Sounds with Respect to Residential Communities;" American National Standard, ANSI S12.4; Acoustical Society of America.

(8) "Guide to the Evaluation of Human Exposure to Vibration in Buildings;" American National Standard, ANSI S3.29-1983; Acoustical Society of America.

(9) Flanagan, Richard F.; "Ground Vibration from TBMs and Shields;" Tunnels & Tunneling; October 1993.

APPENDIX B

EXCERPTS FROM EPA'S ACOUSTIC TERMINOLOGY GUIDE

Descriptor Symbol Usage

The recommended symbols for the commonly used acoustic descriptors based on A-weighting are contained in Table I. As most acoustic criteria and standards used by EPA are derived from the A-weighted sound level, almost all descriptor symbol usage guidance is contained in Table I.

Since acoustic nomenclature includes weighting networks other than "A" and measurements other than pressure, an expansion of Table I was developed (Table II). The group adopted the ANSI descriptor-symbol scheme which is structured into three stages. The first stage indicates that the descriptor is a level (i.e., based upon the logarithm of a ratio), the second stage indicates the type of quantity (power, pressure, or sound exposure), and the third stage indicates the weighting network (A, B, C, D, E.....). If no weighting network is specified, "A" weighting is understood. Exceptions are the A-weighted sound level and the A-weighted peak sound level which require that the "A" be specified. For convenience in those situations in which an A-weighted descriptor is being compared to that of another weighting, the alternative column in Table II permits the inclusion of the "A". For example, a report on blast noise might wish to contrast the LCdn with the LAdn.

Although not included in the tables, it is also recommended that "Lpn" and "LepN" be used as symbols for perceived noise levels and effective perceived noise levels, respectively.

It is recommended that in their initial use within a report, such terms be written in full, rather than abbreviated. An example of preferred usage is as follows:

The A-weighted sound level (LA) was measured before and after the installation of acoustical treatment. The measured LA values were 85 and 75 dB respectively.

Descriptor Nomenclature

With regard to energy averaging over time, the term "average" should be discouraged in favor of the term "equivalent". Hence, Leq, is designated the "equivalent sound level". For Ld, Ln, and Ldn, "equivalent" need not be stated since the concept of day, night, or day-night averaging is by definition understood. Therefore, the designations are "day sound level", "night sound level", and "day-night sound level", respectively.

The peak sound level is the logarithmic ratio of peak sound pressure to a reference pressure and not the maximum root mean square pressure. While the latter is the maximum sound pressure level, it is often incorrectly labelled peak. In that sound level meters have "peak" settings, this distinction is most important.

"Background ambient" should be used in lieu of "background", "ambient", "residual", or "indigenous" to describe the level characteristics of the general background noise due to the contribution of many unidentifiable noise sources near and far.

With regard to units, it is recommended that the unit decibel (abbreviated dB) be used without modification. Hence, DBA, PNdB, and EPNdB are not to be used. Examples of this preferred usage are: the Perceived Noise Level (Lpn was found to be 75 dB. Lpn = 75 dB). This decision was based upon the recommendation of the National Bureau of Standards, and the policies of ANSI and the Acoustical Society of America, all of which disallow any modification of bel except for prefixes indicating its multiples or submultiples (e.g., deci).

Noise Impact

In discussing noise impact, it is recommended that "Level Weighted Population" (LWP) replace "Equivalent Noise Impact" (ENI). The term "Relative Change of Impact" (RCI) shall be used for comparing the relative differences in LWP between two alternatives.

Further, when appropriate, "Noise Impact Index" (NII) and "Population Weighed Loss of Hearing" (PHL) shall be used consistent with CHABA Working Group 69 Report Guidelines for Preparing Environmental Impact Statements (1977).

APPENDIX B (CONTINUED)

TABLE I

A-WEIGHTED RECOMMENDED DESCRIPTOR LIST

TERM	SYMBOL
1. A-Weighted Sound Level	L_A
2. A-Weighted Sound Power Level	L_{WA}
3. Maximum A-Weighted Sound Level	L_{max}
4. Peak A-Weighted Sound Level	L_{Apk}
5. Level Exceeded x% of the Time	L_x
6. Equivalent Sound Level	L_{eq}
7. Equivalent Sound Level over Time (T) (1)	$L_{eq(T)}$
8. Day Sound Level	L_d
9. Night Sound Level	L_n
10. Day-Night Sound Level	L_{dn}
11. Yearly Day-Night Sound Level	$L_{dn(Y)}$
12. Sound Exposure Level	L_{SE}

(1) Unless otherwise specified, time is in hours (e.g. the hourly equivalent level is $L_{eq(1)}$). Time may be specified in non-quantitative terms (e.g., could be specified a $L_{eq(WASH)}$ to mean the washing cycle noise for a washing machine).

SOURCE: EPA ACOUSTIC TERMINOLOGY GUIDE, BNA 8-14-78,

APPENDIX B (CONTINUED)

TABLE II

RECOMMENDED DESCRIPTOR LIST

TERM	A-WEIGHTING	ALTERNATIVE[1] A-WEIGHTING	OTHER[2] WEIGHTING	UNWEIGHTED
1. Sound (Pressure)[3] Level	L_A	L_{pA}	L_B, L_{pB}	L_p
2. Sound Power Level	L_{WA}		L_{WB}	L_W
3. Max. Sound Level	L_{max}	L_{Amax}	L_{Bmax}	L_{pmax}
4. Peak Sound (Pressure) Level	L_{Apk}		L_{Bpk}	L_{pk}
5. Level Exceeded x% of the Time	L_x	L_{Ax}	L_{Bx}	L_{px}
6. Equivalent Sound Level	L_{eq}	L_{Aeq}	L_{Beq}	L_{peq}
7. Equivalent Sound Level[4] Over Time(T)	$L_{eq(T)}$	$L_{Aeq(T)}$	$L_{Beq(T)}$	$L_{peq(T)}$
8. Day Sound Level	L_d	L_{Ad}	L_{Bd}	L_{pd}
9. Night Sound Level	L_n	L_{An}	L_{Bn}	L_{pn}
10. Day-Night Sound Level	L_{dn}	L_{Adn}	L_{Bdn}	L_{pdn}
11. Yearly Day-Night Sound Level	$L_{dn(Y)}$	$L_{Adn(Y)}$	$L_{Bdn(Y)}$	$L_{pdn(Y)}$
12. Sound Exposure Level	L_S	L_{SA}	L_{SB}	L_{Sp}
13. Energy Average Value Over (Non-Time Domain) Set of Observations	$L_{eq(e)}$	$L_{Aeq(e)}$	$L_{Beq(e)}$	$L_{peq(e)}$
14. Level Exceeded x% of the Total Set of (Non-Time Domain) Observations	$L_{x(e)}$	$L_{Ax(e)}$	$L_{Bx(e)}$	$L_{px(e)}$
15. Average L_x Value	L_x	L_{Ax}	L_{Bx}	L_{px}

(1) "Alternative" symbols may be used to assure clarity or consistency.

(2) Only B-weighting shown. Applies also to C,D,E,.....weighting.

(3) The term "pressure" is used only for the unweighted level.

(4) Unless otherwise specified, time is in hours (e.g., the hourly equivalent level is Leq(1). Time may be specified in non-quantitative terms (e.g., could be specified as Leq(WASH) to mean the washing cycle noise for a washing machine.

Appendix M

Potential Construction Vibration Impacts From Trenchless Alternatives and Mitigation Measures Kaneohe / Kailua Force Main No. 2 Kaneohe WWPS To Kailua WWTP

Yogi Kwong Engineers, LLC

December 2010

FINAL SUBMITTAL

LETTER REPORT

POTENTIAL CONSTRUCTION VIBRATION IMPACTS FROM TRENCHLESS ALTERNATIVES AND MITIGATION MEASURES

KANEOHE / KAILUA FORCE MAIN NO. 2

KANEOHE WWPS TO KAILUA WWTP, OAHU, HAWAII

Prepared for:

Austin Tsutsumi & Associates, Inc.
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817

December 2010

Prepared by:

Yogi Kwong Engineers, LLC
1357 Kapiolani Boulevard, Suite 1450
Honolulu, Hawaii 96814

Project No.06040

December 14, 2010

Mr. Ivan K. Nakatsuka, P.E.
Austin Tsutsumi & Associates, Inc.
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817

Subject: Letter Report – Potential Construction Vibration Impacts from Trenchless Alternatives and Mitigation Measures
Kaneohe - Kailua Force Main No. 2
Kaneohe WWPS to Kailua WWTP, Oahu, Hawaii

Dear Mr. Nakatsuka:

As requested, Yogi Kwong Engineers, LLC (YKE) is pleased to submit this Letter Report on Potential Construction Vibration Impacts from Trenchless Alternatives and Mitigation Measures for the above project, for your use. The work was performed in general accordance with our September 18, 2009 Addendum Proposal No. 2 to Austin Tsutsumi & Associates, Inc. Earlier we have submitted a draft copy of this report on May 14, 2010 for project team review and use.

1.0 OVERVIEW OF TRENCHLESS CONSTRUCTION OPTIONS

The proposed Kaneohe / Kailua Force Main No. 2 alignment will involve the installation of a new sewer force main from the Kaneohe Wastewater Pump Station (Kaneohe side) to the Kailua Wastewater Treatment Plant (Kailua side). Detailed descriptions and discussions of the trenchless methods considered along the bay crossing alignments considered, such as horizontal directional drilling (HDD), microtunneling, and tunneling using slurry tunnel boring machines and segmental liner plates as primary liner (slurry TBM), are presented YKE's Preliminary Geotechnical Feasibility Evaluation for Installation of New Sewer Force Main by Trenchless Methods, Kaneohe / Kailua Force Main No. 2, dated January 27, 2010 (Feasibility Report). At this time we understand the project team selected the HDD approach for final design and bidding. Note that the HDD entry/exit point near the H-3 is being re-aligned makai and closer to the MCBH on ramp area to increase the overall turn radius of the pipeline.

Seven (7) preliminary bay-crossing construction approach options were presented in the Feasibility Report. Based on discussions with the project team, and from a geotechnical

Yogi Kwong Engineers, LLC
1357 Kapiolani Blvd. Suite 1450
Honolulu, HI 96814
Tel: (808) 942-0001
Fax: (808) 942-0004

standpoint, Options 5 through 7 were not considered further during the design phase, and this vibration impact study is limited to the installation of a new 36-inch nominal diameter sewer force main under Kaneohe Bay using trenchless methods along the bay crossing alignment presented in Figure 1. For further details on the evaluation of the construction approach options, refer to the Feasibility Report. The four remaining preliminary bay-crossing construction approach options are summarized in the following sections.

Figure 1 – Project Location with trenchless construction alignment options. Scale: 1”=3000’. Reference: USGS, 1998.

1.1 Construction Approach Option 1 – HDD between the Heeia Side of Waikalua Fish Pond and H-3 Interchange

The new sewer alignment for Option 1 (Figure 2) would primarily be installed in a single up to 11,000-foot HDD drill path from the Heeia (northwest) side of the Waikalua Fish Pond to a loop ramp and gore area nearby the H-3 Freeway Interchange.

Figure 2 – Project Location showing Option 1. Scale: 1”=3000’. Reference: Google Earth, downloaded April 2010.

It is anticipated that HDD rigs would be located on both the Kaneohe side and Kailua side of the alignment. Welding and fusing of the steel casing pipes and PVC carrier pipes would be staged on the Kaneohe side, within the City right-of-way at the Kaneohe WWPS and adjacent undeveloped area and also possibly within the now-existing Bayview Golf Course. The area would also be used to stage the pipe segments during steel casing and carrier pipe pullback.

1.2 Construction Approach Option 2 – HDD between the Heeia side of Waikalua Fish Pond and H-3 Interchange with Mid-Bay Connection Shaft

The new sewer alignment would be identical to Option 1 in plan view (Figure 3), except the alignment would be split into two HDD segments, connected at the middle.

Figure 3 – Project Location showing Option 2. Scale: 1”=3000’. Reference: Google Earth, downloaded April 2010.

An overwater drilling platform and an overwater connection shaft would be required between the two HDD segments. The HDD rig would be located on the Kailua side of the alignment, in the same location as Option 1. Welding and fusing of the steel casing pipes and carrier pipes would be staged on the Kaneohe side, similar to Option 1. For one of the HDD segments, the pipe will have to be floated on Kaneohe Bay during pullback. For the other HDD segment, the pipe during pullback can be staged within the City right-of-way at the Kaneohe WWPS and adjacent undeveloped area and also possibly within the now-existing Bayview Golf Course. We understand this option of “mid bay” connection of two HDD installed steel casing pipeline was not selected for bidding based on DEIS preparatory Core Working Group discussions and input.

1.3 Construction Approach Option 3 – Combined Microtunneling Drive(s) and HDD Methods

The new sewer alignment would be identical to Option 1 in plan view (Figure 4), except the alignment would be split into one HDD segment, and one microtunneling segment at the Kaneohe end of the alignment.

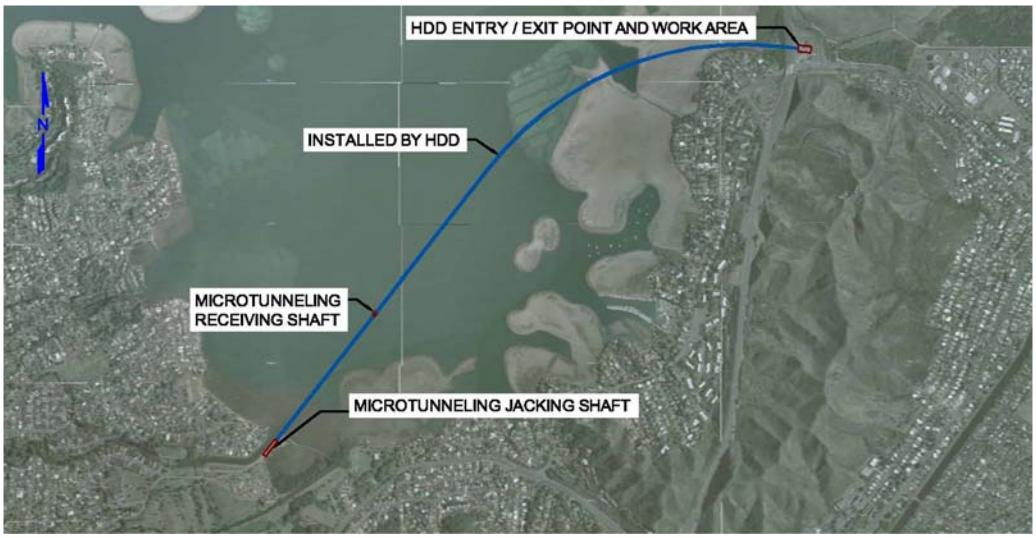


Figure 4 – Project Location showing Option 3. Scale: 1”=3000’. Google Earth, downloaded April 2010.

A microtunneling jacking shaft would be located on the Kaneohe side of the alignment, nearby the HDD entry point for Options 1 and 2. An overwater receiving/connection shaft would be required between the microtunneling and HDD segments. The HDD rigs would be located at the same locations as Option 1. Welding and fusing of the steel casing pipes and carrier pipes would be staged on the Kaneohe side, similar to Option 1. The area would also be used to stage the pipe segments during pullback. The contingency measures provided for bidding of option 1 may include this approach, depending on bidders’ evaluation of risks and construction difficulties.

1.4 Construction Approach Option 4 – Tunneling Using Slurry TBM and Segmental RC Liner

The new sewer alignment would be identical to Option 1 in plan view (Figure 5), except the new sewer line would be installed using conventional tunneling methods. Entry and exit portals would be required on both sides of the alignment. This option is not selected for bidding at this time due to costs and funding constraints.

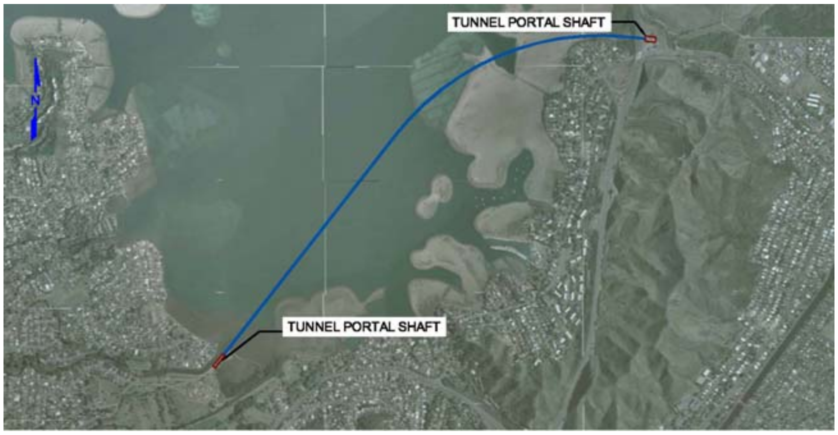


Figure 5 – Project Location showing Option 4. Scale: 1"=3000'. Google Earth, downloaded April 2010.

1.5 Site Surface Conditions

The FHWA Transit Noise and Vibration Impact Assessment manual (FHWA, 2006), outline three categories of land-use for vibration impact assessment. Category 1 (High Sensitivity) includes vibration-sensitive research and manufacturing, hospitals with vibration-sensitive equipment, and university research operations. Category 2 (Residential) includes all residential land uses and any buildings where people sleep, such as hotels and hospitals. Some hospitals may include MRI machines, which necessitate lower thresholds of vibrations. Category 3 (Institutional) includes schools, churches, other institutions, and quiet offices that do not have vibration-sensitive equipment, but still have potential for activity interference. Other buildings (Special Buildings), such as concert halls, TV and recording studios, and theaters, do not fit into any of the three categories, but are considered to be vibration-sensitive.

Based on available information, including site reconnaissance, land-use within ¼ mile of the project area can be classified as Vibration Category 2 (Residential) and 3 (Institutional). Residential homes, primarily consisting of one- to two-story wooden structures supported on spread footings, are located within ¼ mile on each end of the alignment, and along the shoreline of Kaneohe Bay.

The immediate vicinity of the Kaneohe WWPS side of the alignment includes the Heeia side of the Waikalua Fish Pond, Bayview Golf Course, and Kaneohe WWPS. These sites will be used as staging areas for the HDD rigs, for launch pits for driving protective casing or "conductor barrel" in support of the HDD operations, to prevent inadvertent mud return on the Kaneohe entry/exit location. Some bidders may elect to jack a larger diameter steel casing to reduce pile driving noise and vibration and may use this area to construction a launch pit for pipe jacking operations. The existing Kaneohe WWPS and possibly the adjacent Bayview Golf Course may also be used for pipe staging, fusing, and welding. Residential homes, primarily consisting of one- to two-story wooden structures supported on spread footings, are located on the opposite bank of Kaneohe Stream, about 300 to 500 feet from the proposed staging and work areas at these locations. Kaneohe Beach Park, YWCA, Puohala Elementary School, Castle High School, and several churches are located over 1,000 feet from the project area. Kaneohe Shopping Center and Windward Shopping Center are located approximately 1 mile northwest and southwest of the project area, respectively.

The bay crossing alignment will traverse under Kaneohe Bay. Base on the HDD bid option (Option 1), overwater work is expected to be limited to contingency measures or emergency work to control or prevent inadvertent mud returns such as temporary placement of silt curtains and steel sheet piles containment, over water excavation(s) to correct pilot drill path connection problems/issues, and to removal unforeseen obstructions or in-hole tools or equipment. Contingency overwater excavation is expected to be limited to 50 feet by 50 feet area and only in areas underlain by estuarine mud, with no live sea grass and coral.

Residential homes, primarily consisting of one- to two-story wooden structures supported on spread footings, are located along the shoreline of Kaneohe Bay. Three City wastewater pump stations and the Kaneohe Yacht Club are also located along the shoreline. These residences and facilities are over 2,000 feet from the potential overwater work areas.

The Kailua WWTP side of the alignment includes the loop ramp and gore area nearby the H-3 Freeway Interchange. The site will be used as staging areas for the HDD rigs, for on land pipeline section auger/guided boring jacking shafts, and open trenching installation of parts of the new force main. A Hawaiian Electric Company substation is located south of the project area. Aikahi Elementary School and Aikahi Shopping Center are located approximately 0.5 miles and 0.75 miles east of the project area, respectively. Kaneohe Marine Corps Base is located approximately 0.5 miles north of the project area.

1.6 Regional Geology and Anticipated Site Subsurface Conditions

The regional geology of the project area is shown on Figure 6. The island of Oahu was built by two volcanoes, the older Waianae volcano of the Waianae Volcanic series in the west and the younger Koolau volcano of the Koolau Volcanic series in the east. Each volcano has been truncated by a massive submarine landslide, the Waianae Slump to the southwest and the Nuuanu Slide to the northeast. The Waianae volcano have ages dated from about 4.0 Ma to 2.9 Ma, while the Koolau volcano have ages dated from about 3.0 Ma to 1.78 Ma (Sherrod et al, 2007). The Koolau basalts within the project area are identified as QTkkl, QTkkdc, and

QTkkbr on Figure 6, Regional Geology Map. The dike complex is also identified on the Regional Geology Map, and is exposed in the hills between the crest of the range and Kaneohe Bay and near the heads of the big valleys farther north (MacDonald, 1983).

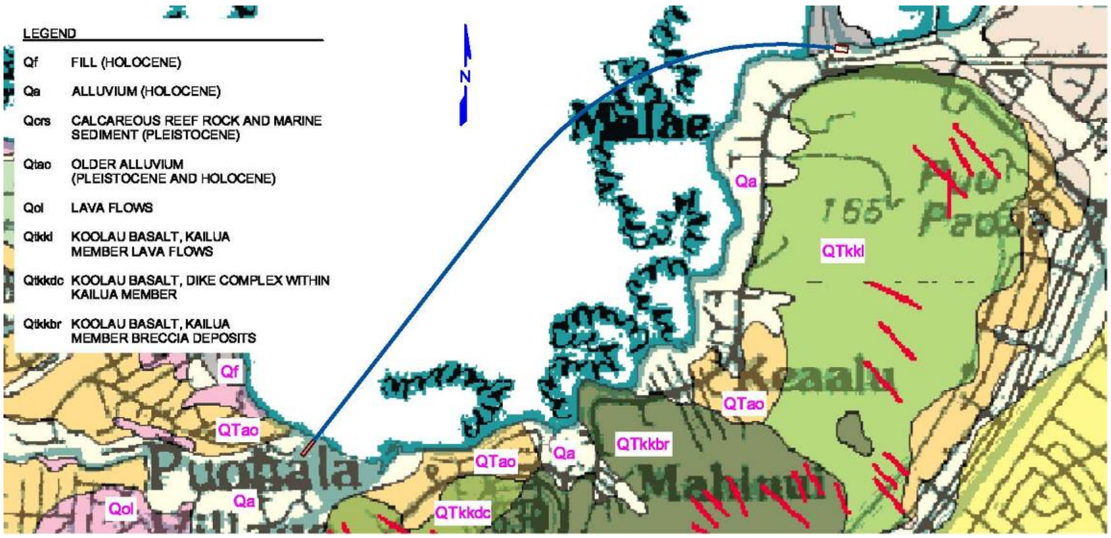


Figure 6 – Regional Geology. Scale: 1”=3000’. Reference: Sherrod et al, 2007, Geologic Map of the State Of Hawaii.

The end of the post-shield stage was followed by a period of erosion and subsidence, during which deep canyons formed along the flanks of the volcano. As the islands subsided, fringing coral reefs grew, resulting in back reef sedimentary environment that traps lagoonal or estuarine silts and clays and wave worked calcareous sands and gravels. Where massive fringing reef blocking estuaries, such as in Kaneohe Bay, over 100 feet of N=0 sandy silts are trapped behind the reef. As the sandy silts accumulate and the sediment influx diminished, coral reef can form over the very soft sediments. Recent overwater geotechnical exploration in Kaneohe Bay revealed the back-reef coral growth and rubble can be 40 feet thick and induced some consolidation settlement of the very soft estuarine silts, but the SPT blow counts were still low, less than N=2, to 100 feet below mean sea level (MSL).

During past interglacial periods, the sea level rose above the present level, followed by a regression of the sea level to well below the present level during the glacial stages. These cycles of advance and retreat of the sea have produced reef deposits and later coralline limestone at varying levels, identified as Qcrs on the Regional Geology Map.

A great amount of the Waianae and Koolau Ranges was removed by fluvial and marine erosion during the Pleistocene, creating deep valleys. After these erosion cycles, the island was submerged more than 1,200 feet, and the valleys were drowned and alluviated. Along with this submergence, regressions and transgressions of sea level occurred, which resulted in renewed erosion of the higher deposits, and growth of coral offshore. During periods of low sea level, alluvial channels (valleys), identified as Qa and QTao on the Regional Geology Map, and erosional surfaces developed which extend well below the current mean sea level, can be found interbedded within the reef deposits.

2.0 EXISTING VIBRATION CONDITIONS

Based on the proposed work and staging areas, four measurement sites were selected, as shown on Figure 7.

Figure 7 – Approximate Locations of Seismograph Measurement Sites. Scale: 1”=1000’.
Reference: USGS, 2005; Hawaii Aviation, 2008.

An Instantel BlastMate Series III seismograph, serial number 16171, last calibrated by Instantel on September 30, 2009, was used to record the ambient levels at each site. The transducer was affixed to the ground using the three ground spikes that were included with the apparatus, and the arrow at the top of the transducer was pointed along the alignment. The histogram record mode was selected. The seismograph sampled data continuously at a sampling rate of 4096 samples per second, but only stored the relevant peaks in the longitudinal, transverse, and vertical directions, at every 2-second interval. For each interval, the seismograph calculated the maximum positive and negative peaks, the frequency of the largest peak, and up to two peak vector sums. Ambient levels were recorded for periods of approximately 15 minutes. Vibration data for each site, including the Peak Particle Velocities (PPV) during the tested time periods, are included in the Attachments.

The recorded data shows ambient levels of vibration, recorded as PPV, ranging from 0.001874 in/sec to 0.02311 in/sec. Table 1 summarizes the range of ambient levels of PPV for each measurement site.

Measurement Site	Range of PPV (in/sec)			Recording Period
	Trans.	Vertical	Long.	
Site 1 – Waikalua Fish Pond near Kaneohe Bay shoreline	.001874 to .003126	.001874 to .003126	.001874 to .003126	2010-03-18 10:36-10:51
Site 2 – Waikalua Fish Pond and Kaneohe WWPS	.001874 to .003748	.001874 to .003126	.001874 to .00437	2010-03-18 11:07 – 11:22
Site 3 – Waikalua Fish Pond and Bayview Golf Course	.001874 to .02311	.001874 to .01563	.001874 to .01189	2010-03-18 11:40 – 11:55
Site 4 – YWCA near Kaneohe Bay shoreline	.001874 to .00437	.001874 to .00437	.001874 to .00937	2010-03-18 12:35 – 12:50
Site 5 – H-3 Interchange	.001874 to .00626	.001874 to .003126	.001874 to .00563	2010-03-18 13:41 – 13:56

Table 1 – Ambient Levels of PPV at Measurement Sites.

The majority of the ambient levels of PPV are lower than the threshold of perception for humans of 0.01 in/sec PPV, and comparable to the typical background vibration velocity levels of 0.003 in/sec PPV in residential areas used by the FHWA Transit Noise and Vibration Impact Assessment manual (2006). Higher recorded vibration peaks during the vibration monitoring were due to vehicles passing nearby the seismograph.

3.0 VIBRATION IMPACT CRITERIA

According to the FHWA (2006), the level of vibration that causes annoyance is often only slightly higher than the threshold of perception, though it will be well below the threshold for damage for normal buildings (less than 0.2 in/sec, dependent on proximity and condition of existing structures and sites of interest). Furthermore, ground-borne vibration is almost never annoying to people who are outdoors, as although ground motion may be perceived, without the effects associated with the shaking of the building, the motion does not often provoke the same adverse human reaction. In addition, the rumble noise that usually accompanies the building vibration is perceptible only inside of buildings. Typical indoor sources of perceptible vibration are movement of people, slamming of doors, air conditioning, mechanical equipment, etc. Typical outdoor sources include construction equipment and traffic on rough roads.

Numerous studies have been conducted to evaluate the human response to steady state vibration. The California DOT Transportation- and Construction- Induced Vibration Guidance Manual (Caltrans, 2004) summarized the guidelines for vibration annoyance criteria, and also provided guidelines for vibration damage criteria. These guidelines are presented in Tables 2 and 3.

Human Response	Maximum PPV (in/sec)	
	Transient Sources	Continuous / Frequent / Intermittent Sources
Barely perceptible	0.04	0.01
Distinctly perceptible	0.25	0.04
Strongly perceptible	0.9	0.10
Severe	2.0	0.4

Table 2 – Guideline Vibration Annoyance Potential Criteria. Reference: Caltrans, 2004.

Structure and Condition	Maximum PPV (in/sec)	
	Transient Sources	Continuous / Frequent / Intermittent Sources
Extremely fragile historic buildings, ruins, ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5

Table 3 – Guideline Vibration Damage Potential Criteria. Reference: Caltrans, 2004.

4.0 PREDICTIONS OF VIBRATION FROM THE PROJECT

The FHWA Transit Noise and Vibration Impact Assessment report (FHWA, 2006) recommended that the vibration impact from construction activities can be estimated using the following equation:

$$PPV_{Equip} = PPV_{Ref}\,(25/D)^{1.5}\ (in/sec) \qquad (Eq.\ 1)$$

where: PPV_{Equip} = the PPV of the equipment adjusted for distance.
PPV_{Ref} = the reference PPV at 25 feet
D = distance from the equipment to the receiver

FHWA (2006) and Caltrans (2004) provided approximate reference PPV for various types of construction equipment under a wide variety of construction activities, and are summarized in Table 4.

Equipment		**Reference PPV at 25 feet (in/sec)**
Crack-and-seat operations		2.4
Pile driver (impact)	upper range typical	1.518 0.644
Pile driver (sonic)	upper range typical	0.734 0.170
Vibratory hammer		0.65
Vibratory roller		0.210
Clam shovel drop (slurry wall)		0.202
Hoe ram		0.089
Large bulldozer		0.089
Caisson drilling		0.089
Loaded trucks		0.076
Jackhammer		0.035
Hydromill (slurry wall)	in soil in rock	0.008 0.017
Small bulldozer		0.003

Table 4 – Vibration Source Levels for Construction Equipment. Reference: FHWA, 2006, Caltrans, 2004.

An assessment of potential vibrations generated by the proposed sewer construction, an evaluation of collected seismograph data collected by YKE during past sewer construction in Kailua and Honolulu, Oahu, was performed. The vibration methods were obtained during sheetpile driving using a hydraulic hammer with a rated energy of 24,000 lb-ft in Kailua, Hawaii; sheetpile installation using a vibratory hammer in Honolulu, Hawaii; and sheetpile removal using a vibratory hammer previously installed using a hydraulic hammer in Kailua, Hawaii. Summaries of the data are presented in Figures 8 through 10.

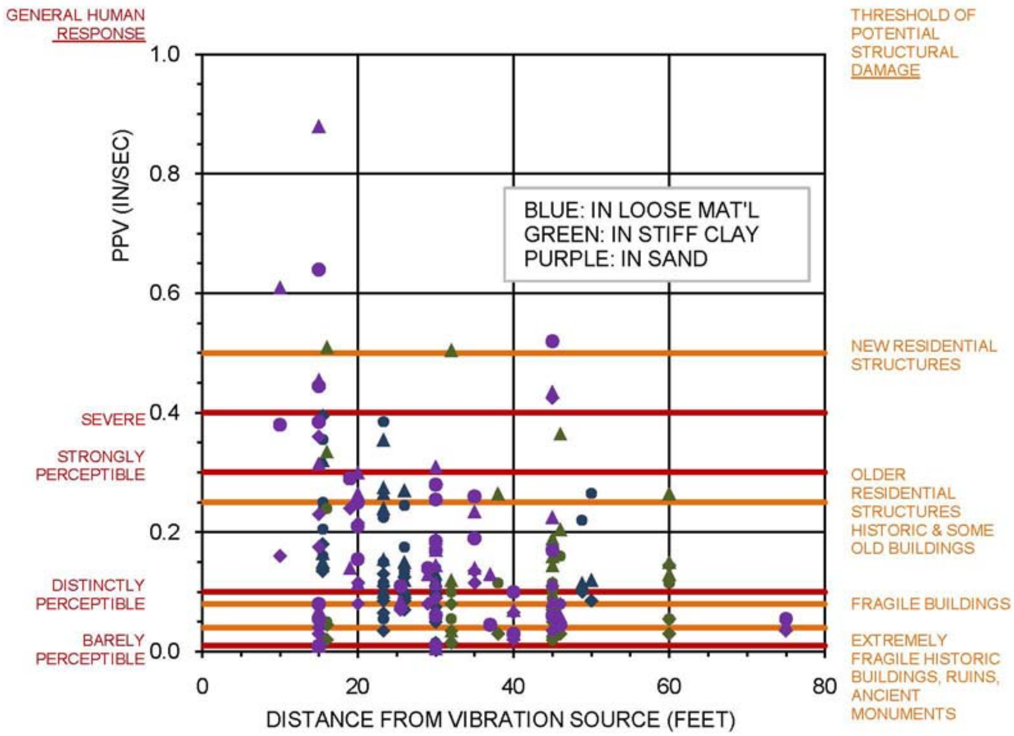


Figure 8 – Installation of sheetpiles using a diesel impact hammer in Kailua, Hawaii.

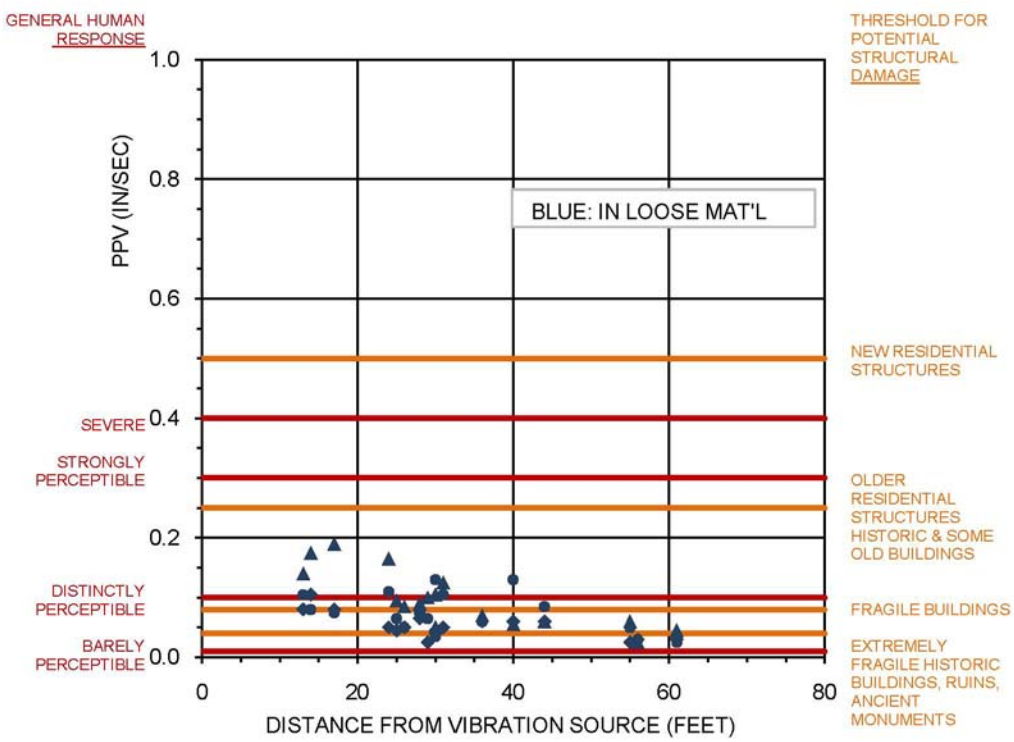


Figure 9 – Installation of sheetpiles using a vibratory hammer in Honolulu, Hawaii.

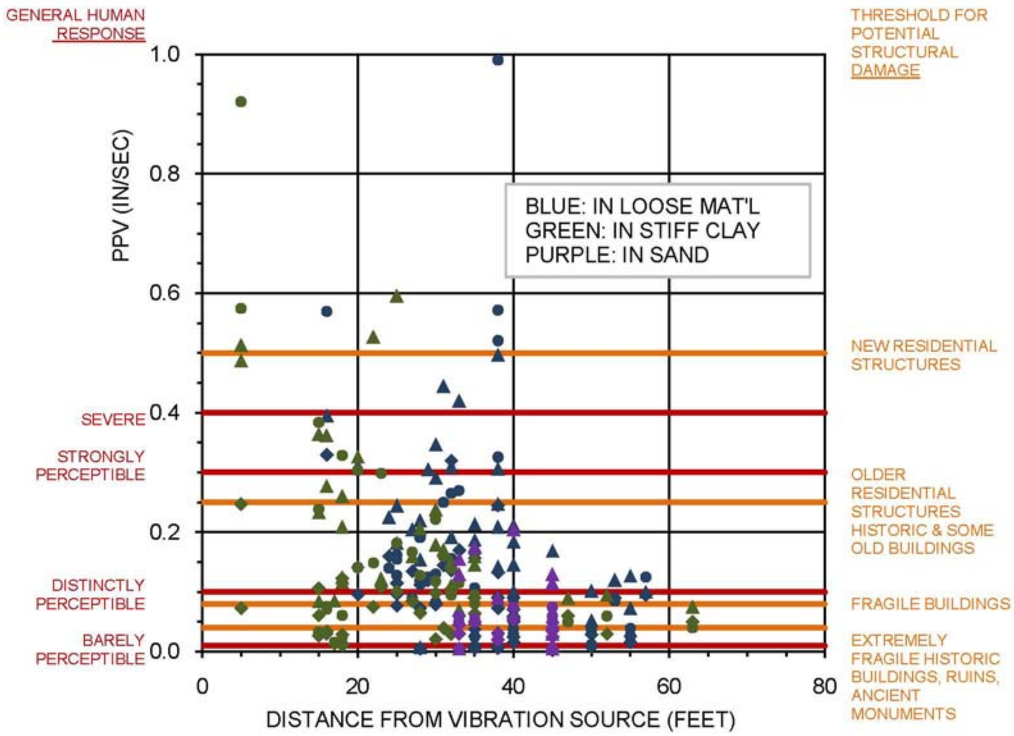


Figure 10 – Removal of sheetpiles using a vibratory hammer in Kailua, Hawaii.

Based on past project seismograph data, reference PPV for sheetpile driving and removal can be estimated (Table 6). It should be noted that the sheet pile driving locations were pre-drilled to break up all obstruction prior to driving, otherwise the vibration generated may be higher.

Construction Activity		**Reference PPV at 25 feet (in/sec)**
Installation of sheetpiles using an hydraulic hammer	in loose mat’l in stiff clay in sand	0.38 0.30 0.34
Installation of sheetpiles using a vibratory hammer	in loose mat’l	0.16
Removal of sheetpiles using a vibratory hammer	in loose mat’l in stiff clay	0.40 0.30

Table 5 – Vibration Source Levels for Construction Activities.

The typical vibration amplitudes given in Table 5 for sheetpile installation using a hydraulic hammer and vibratory hammer are lower than the reference PPVs given in Table 4, and less than that of a vibratory roller.

Figure 11 compares damage thresholds versus the measured ground vibrations of the sheetpile driving using a hydraulic hammer with a rated energy of 24,000 lb-ft in Kailua, Hawaii; sheetpile installation using a vibratory hammer in Honolulu, Hawaii; and sheetpile removal using a vibratory hammer previously installed using a hydraulic hammer in Kailua, Hawaii.

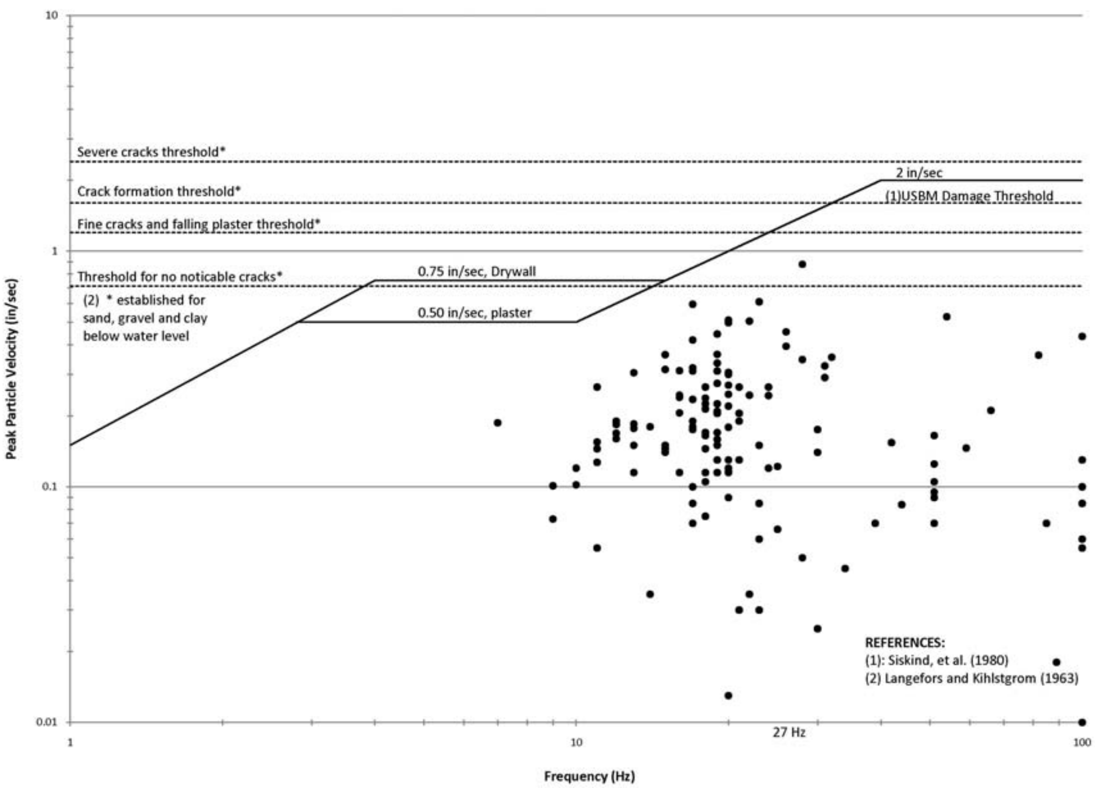


Figure 11 – Measured Ground Vibrations Compared Against Damage Thresholds

Based on a past project involving HDD starter casing installation in Bellevue, Washington, provided by an HDD contractor, PPV ranged from 0.05 to 2 in/sec when the geophone was set up 16 feet to 50 feet away from the alignment.

Based on past experience on previous trenchless construction in Hawaii, vibrations are generally seldom felt at the ground surface, even when standing directly above the 20-foot or deeper below-ground trenchless equipment. Vibrations resulting directly from trenchless construction are expected to fall below the levels of human perception (approximately less than 0.01 in/sec PPV), and thus below the levels of potential structural damage, within very short distances of within 10 to 20 feet. If the HDD support “conductor barrel” or protective casing, probably 48-inch to 60-inch in diameter is installed by drilling (using the HDD rig) or jacking (using pipe jacking methods) into the very soft silts, no perceptible vibration is expected at the work site boundaries. If a pile driving hammer, such as a hydraulic or compressed air hammer, or compressed air driven pneumatic pipe ramming hammer is used, the driving of the casing into the very soft silt is expected to generate vibration similar to driving sheet piles and should be monitored.

4.1 Other Factors Affecting Vibrations

In addition to the source and distance, other factors that may influence the levels of ground-borne vibrations include the site geology and the receiving building. These factors are summarized in Table 6 below. It should be noted that geologic conditions that promote efficient propagation have not been well documented or fully understood.

Factor Related to Vibration Path	**Influence**
Soil Type	Vibration levels are generally higher in stiff clay-type soils than in loose sandy soils.
Rock Layers	Vibration levels are usually high when the depth to bedrock is 30 feet or less. Because of efficient propagation, the vibration level does not attenuate as rapidly in rock as it does in soil.
Soil Layering	Soil layering will have a substantial, but unpredictable, effect on the vibration levels since each stratum can have significantly different dynamic characteristics.
Depth to Water Table	The presence of the water table may have a significant effect on ground-borne vibration, but a definite relationship has not been established.
Factor Related to Vibration Receiver	**Influence**
Foundation Type	The general rule-of-thumb is that the heavier the building foundation, the greater the coupling loss as the vibration propagates from the ground into the building.
Building Construction	Since ground-borne vibration and noise are almost always evaluated in terms of indoor receivers, the propagation of the vibration through the building must be considered. Each building has different characteristics relative to structure-borne vibration, although the general rule-of-thumb is the more massive the building, the lower the levels of ground-borne vibration.
Acoustical Absorption	The amount of acoustical absorption in the receiver room affects the levels of ground-borne noise.

Table 6 – Relevant Factors that Influence Levels of Ground-Borne Vibration. Reference: FHWA, 2006.

Previous subsurface investigation at the site indicates that the project area is underlain by basalt rock at depths 40 to 70 feet deep, with some soil borings not encountering basalt to the end of boring at 100 feet deep. Based on the regional geology and available subsurface information, it is not anticipated that the hard basalt rock is shallow or close enough to affect the propagation of vibrations that will significantly impact existing structures near the trenchless alignment. However, the stiff soils near the H-3 interchange may propagate vibrations more efficiently.

5.0 VIBRATION IMPACT ASSESSMENT

Equipment and activities related to trenchless construction that typically generate vibration include:

- Trenchless equipment, such as HDD rigs, pipe jacking/microtunneling jacking frames, pipejacking/microtunnel boring machine, tunnel boring machine, slurry separation plants with generators.
- Impact hammers used to drive HDD steel starter casings ("conductor barrels", protective casings) into the ground. Construction is similar to pile driving, except that the steel casing is at an angle, with typical installation angles ranging from 8 degrees to 12 degrees from the horizontal.
- Shaft construction equipment, such as jet grout drilling rigs, vibratory hammers for sheet piles, impact pile drivers for sheet piles.
- Excavation equipment, such as excavators, dump trucks, cranes with clam-shell buckets, hoe-rams, jack hammers with air compressors.
- Compaction equipment, such as static and vibratory rollers, used during backfilling of the shafts used for trenchless construction.

Typically, vehicles such as work trucks do not impart vibrations unless the roadway pavement is not smooth. Trenchless equipment and other construction equipment associated with trenchless construction are also not anticipated to exceed significant vibration perception or damage thresholds. Other equipment associated with trenchless construction, including air compressors, generators, trucks, loaders, cranes, and other typical construction equipment, are not expected to generate vibrations above the level of barely perceptible human perception for structures nearest the project alignment.

The highest ground-borne vibrations during construction will likely result from sheetpile driving and removal, HDD starter casing installation, and vibratory rollers are expected to generate the highest vibrations during work related to trenchless construction, with reference PPV at 25 feet of up to approximately 0.2 in/sec.. The work is expected to be limited to the project areas on the Kaneohe and Kailua sides of the alignments, and with the exception of vibratory rollers, at overwater shaft locations along the alignment. Equation 1 from Section

4.0 and the reference PPV given in Table 5 can be used to determine the distances for various thresholds. The results are shown on Tables 7 and 8.

Human Response	Threshold PPV (in/sec)	Approximate Distance (feet)
Barely perceptible	0.04	135
Distinctly perceptible	0.25	40
Strongly perceptible	0.9	17
Severe	2.0	10

Table 7 – Vibration Annoyance threshold distances for sheetpile installation / removal, HDD steel starter casing installation using impact hammer, and vibratory rollers.

Structure and Condition	Threshold PPV (in/sec)	Approximate Distance (feet)
Extremely fragile historic buildings, ruins, ancient monuments	0.12	65
Fragile buildings	0.2	47
Historic and some old buildings	0.5	25
Older residential structures	0.5	25
New residential structures	1.0	16
Modern industrial/commercial buildings	2.0	10

Table 8 – Vibration damage threshold distances for sheetpile installation / removal, HDD steel starter casing installation using impact hammer, and vibratory rollers.

Based on the calculated data, the vibrations resulting from sheetpile driving will be barely perceptible within 135 feet of the vibration source. The closest structures to work areas involving potential sheet pile driving are located on the Kaneohe side of the alignment, where residential homes on the opposite bank of Kaneohe Stream are within 300 feet.

Therefore, the anticipated equipment and activities related to trenchless construction are not expected to generate vibrations exceeding the given thresholds for structural damage of the known nearest structures and buildings. However, it is possible that the anticipated construction-related vibrations will generate vibrations that may reach the given thresholds for barely perceptible human response. Thus, mitigation measures are suggested in the following section.

6.0 MITIGATION MEASURES

Based on the vibration impact assessment, the highest ground-borne vibrations during construction will likely result from sheetpile driving and removal, HDD starter casing installation, and vibratory rollers. To further minimize the possibility of vibration levels exceeding the thresholds for human perception and structural damage, mitigations measures can be implemented during sheetpile installation / removal. Mitigation measures can include:

- Predrilling to break up boulders prior to sheetpile installation.
- Excavation of appropriate trenches near the vibration source between potential sensitive areas and the vibration source, such as at the pipe ramming or driving location on land, to accelerate decay of vibration energy.
- Recommend the use of hydraulic impact pile driving or press-in-piling systems that use hydraulic static loading and previously installed sheet piles as reaction piles to install the sheet piles, and prohibiting the use of diesel impact hammers and limit vibratory hammers usage to pulling sheets out of very soft mud.
- If impact pile driving is chosen, pile cushioning can increase the period of time over which the energy from the driver is imparted to the pile, and thus reduce the resultant vibrations.
- Scheduling construction during business hours on weekdays, while many residents will be at work and thus not affected.
- Leaving sheet piles in-place after construction, and cutting off the top 5 feet in the event of future utility installation. Removing the sheet piles after construction using a vibratory hammer may result in excessive vibrations.

Mitigation measures are limited to minimizing vibrations during sheet pile installation. In addition to the mitigation measures listed above, vibration monitoring during sheetpile driving should be conducted. Although vibration monitoring by itself will not reduce vibration impacts, it can help determine whether vibration levels are excessive and requires the implementation of further mitigation measures. If casings are driven into the ground during HDD operations, vibration monitoring should also be conducted.

7.0 REFERENCES

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U.S.G.S. Topographic Map, Mokapu Quadrangle, 1998. United States Geologic Services.

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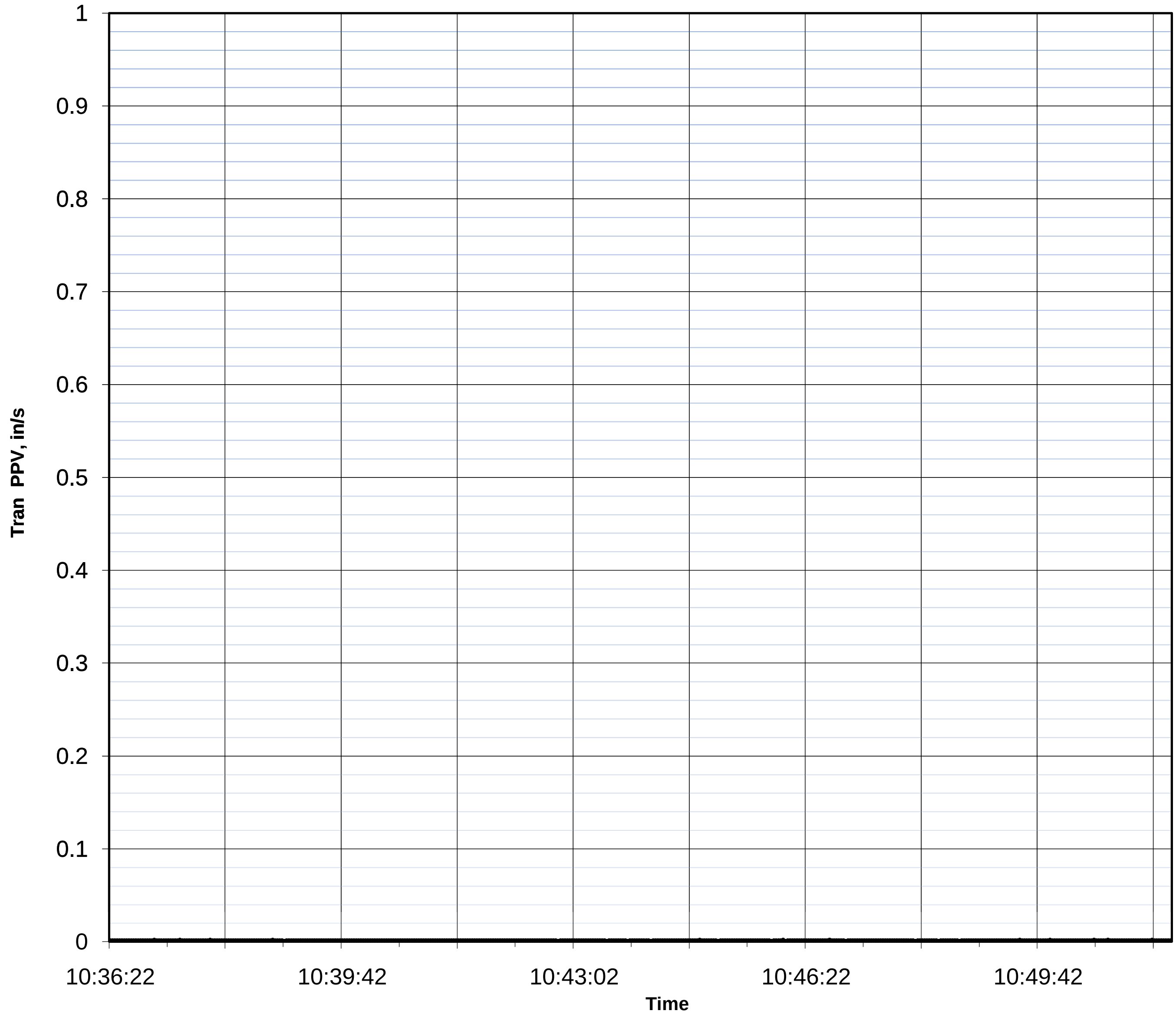
We appreciate the opportunity to provide these services to Austin Tsutsumi & Associates, Inc. If you have any questions regarding this letter report, please do not hesitate to contact us.

Yours truly,
Yogi Kwong Engineers, LLC.

Devin D. Nakayama, P.E.
Project Engineer

James Kwong, Ph.D., P.E.
Principal

Attachments: YKE seismograph data of ambient conditions at selected sites



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Tran Peak Date:	3/18/10
Tran PPV (in/sec):	0.003

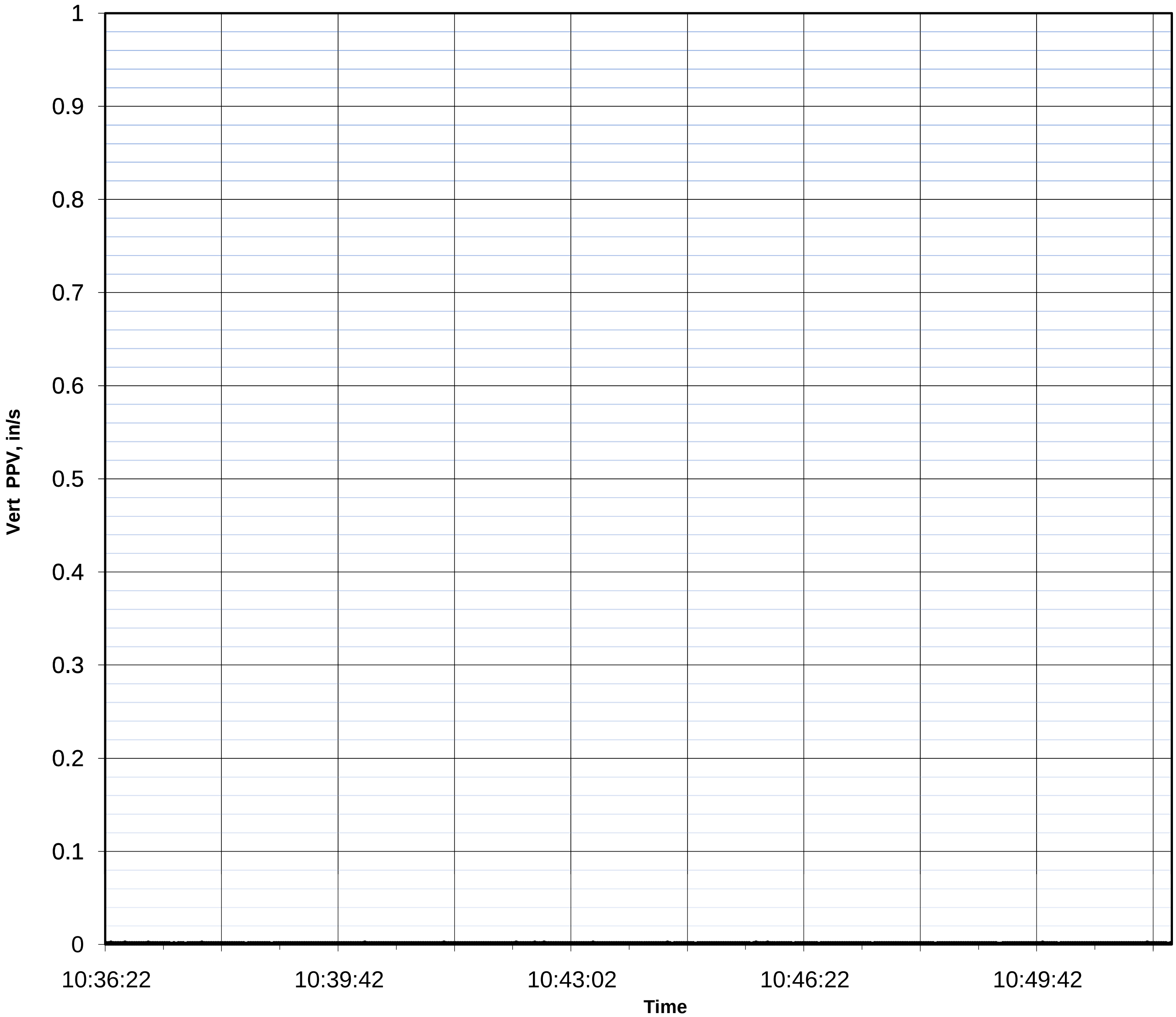
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Tran PPV



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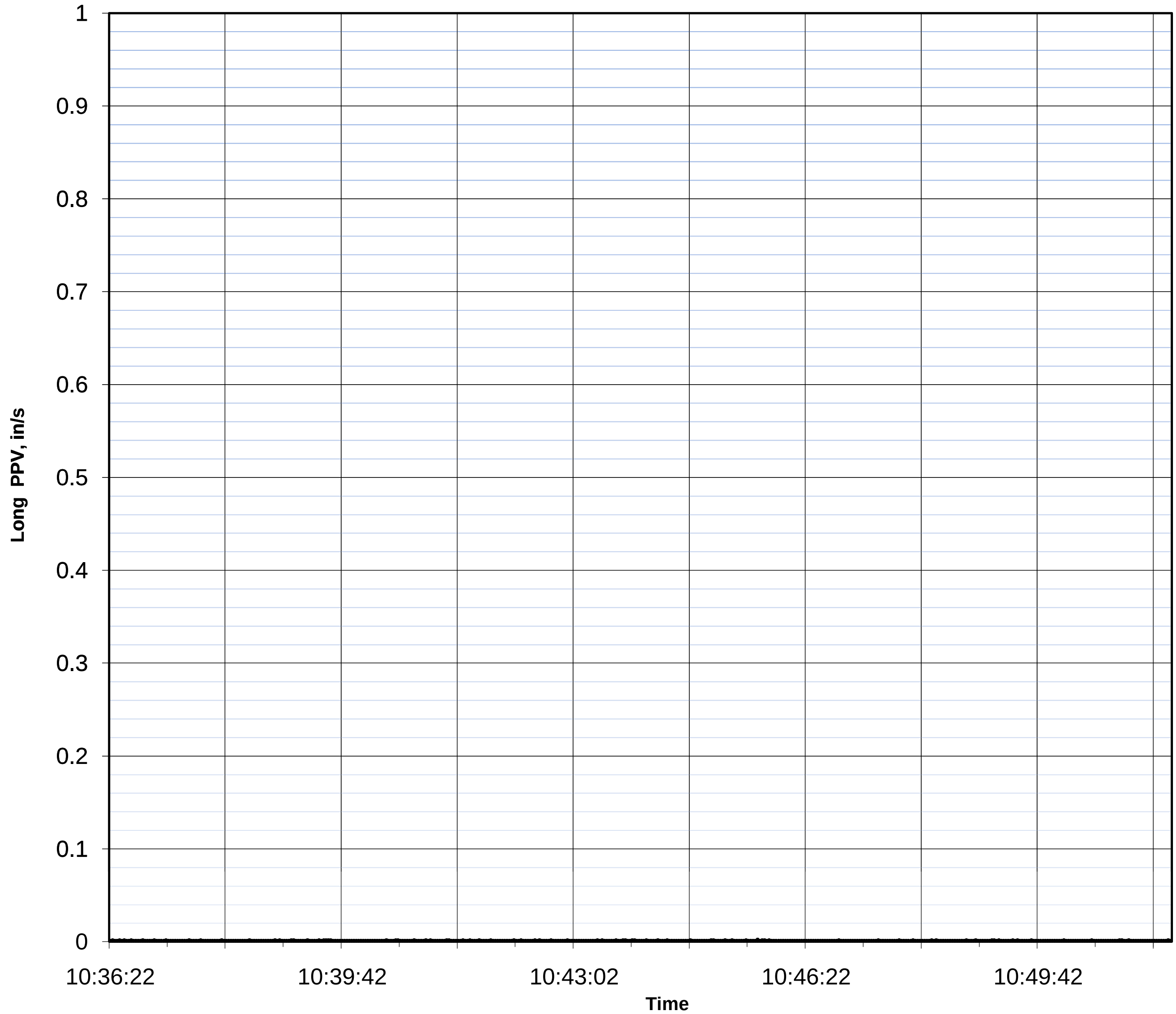
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Vert PPV



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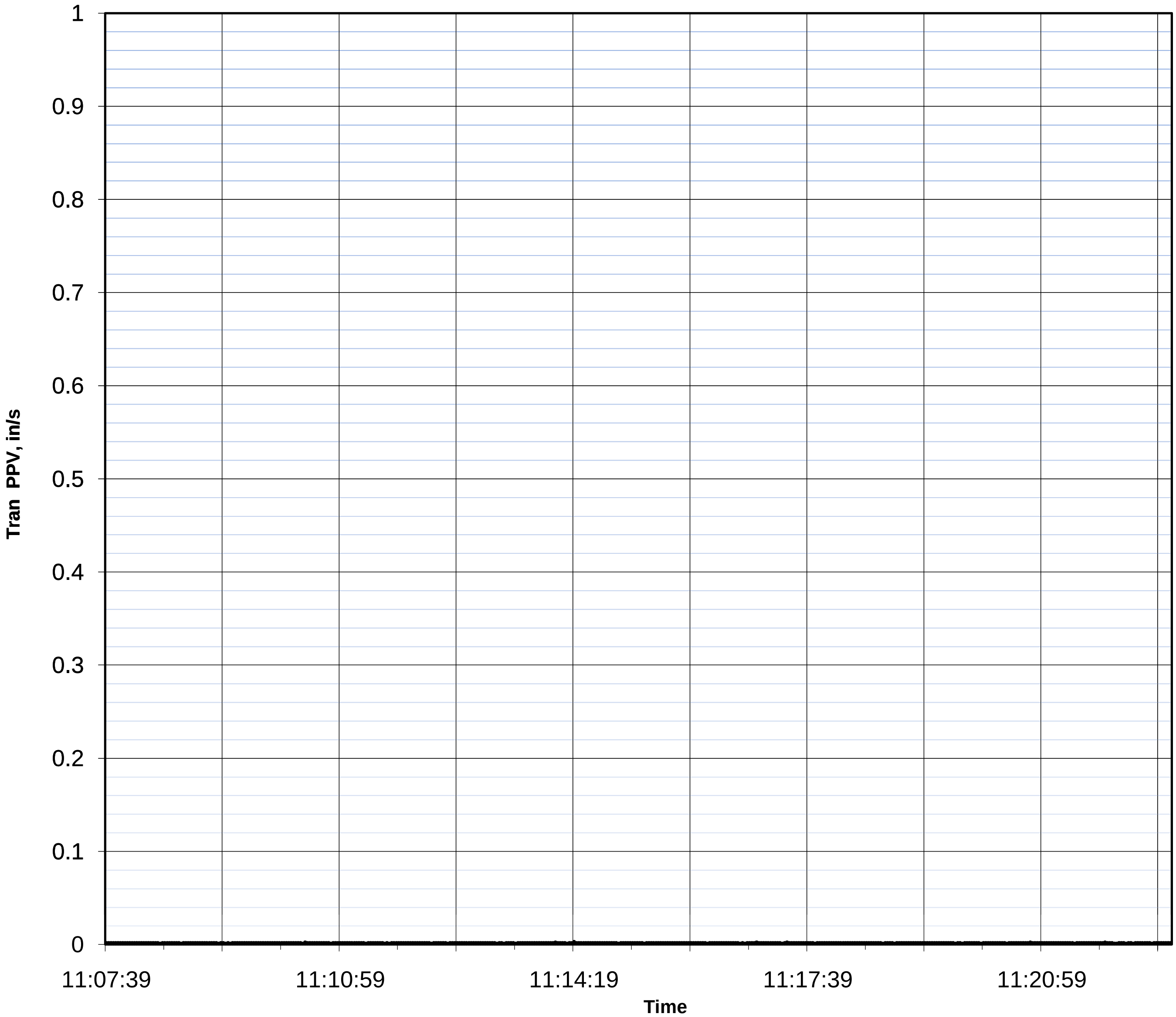
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

YKE Yogi Kwong Engineers, LLC

Long PPV



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Tran PPV (in/sec):	0.004

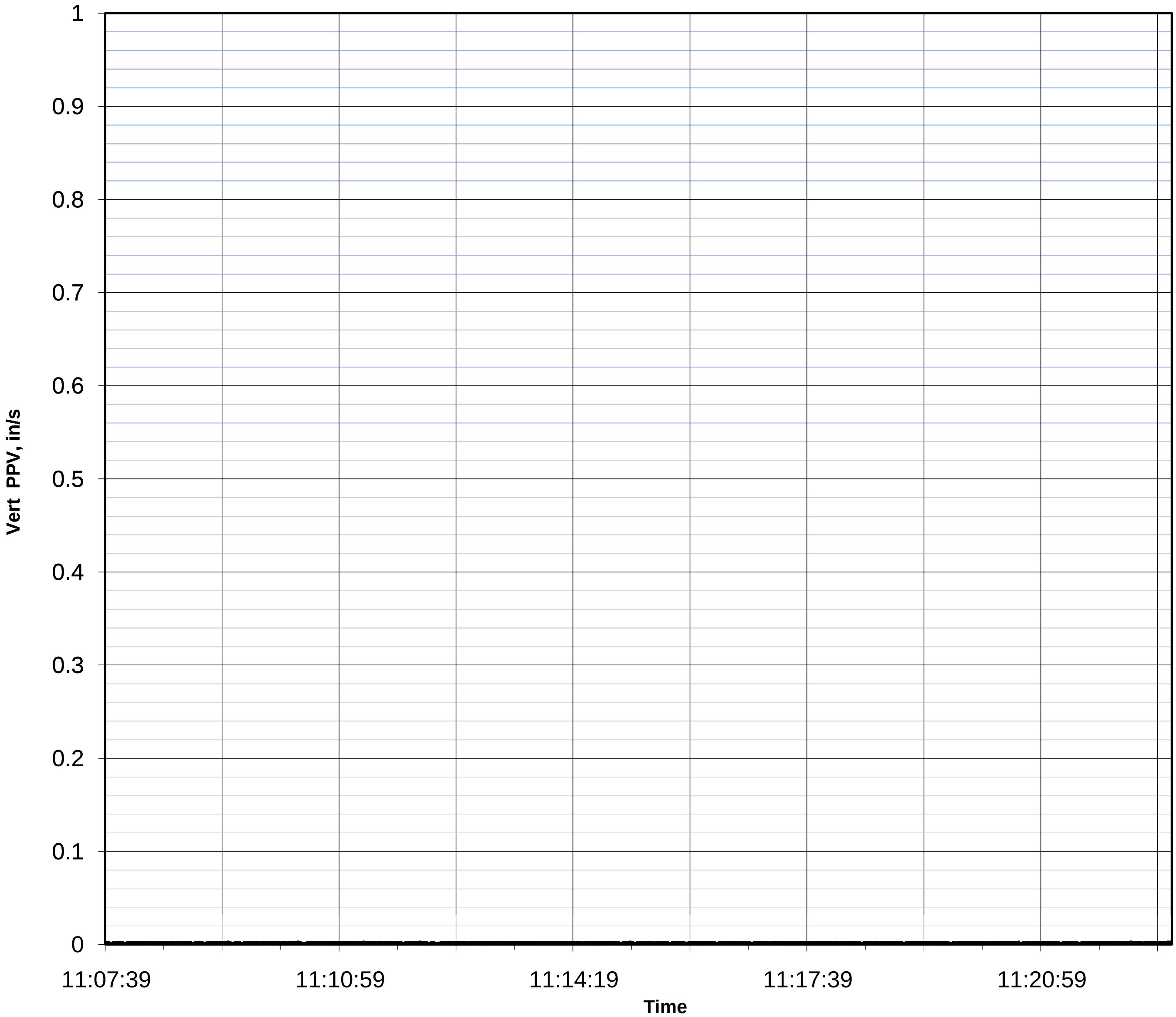
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Tran PPV



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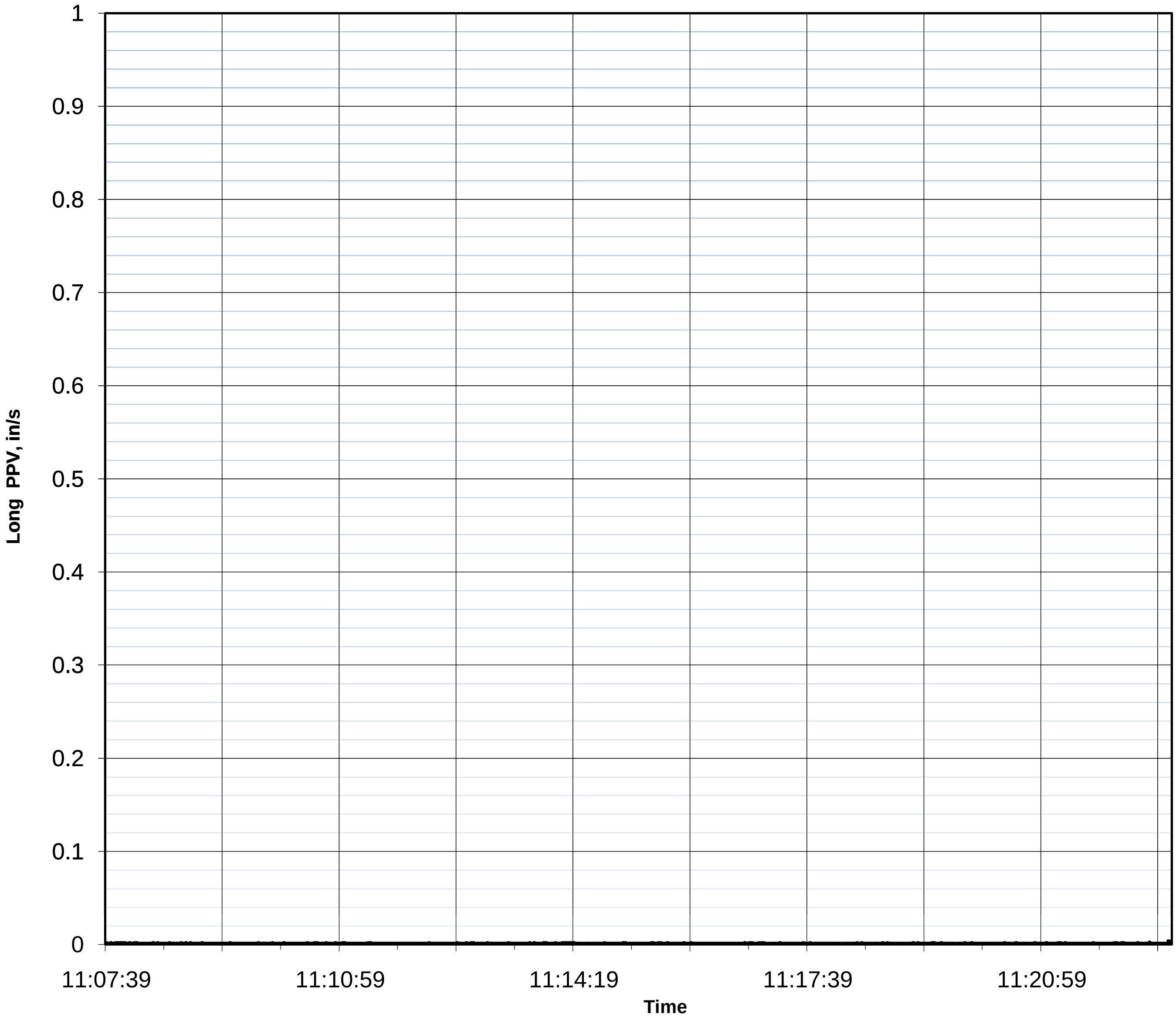
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Vert PPV



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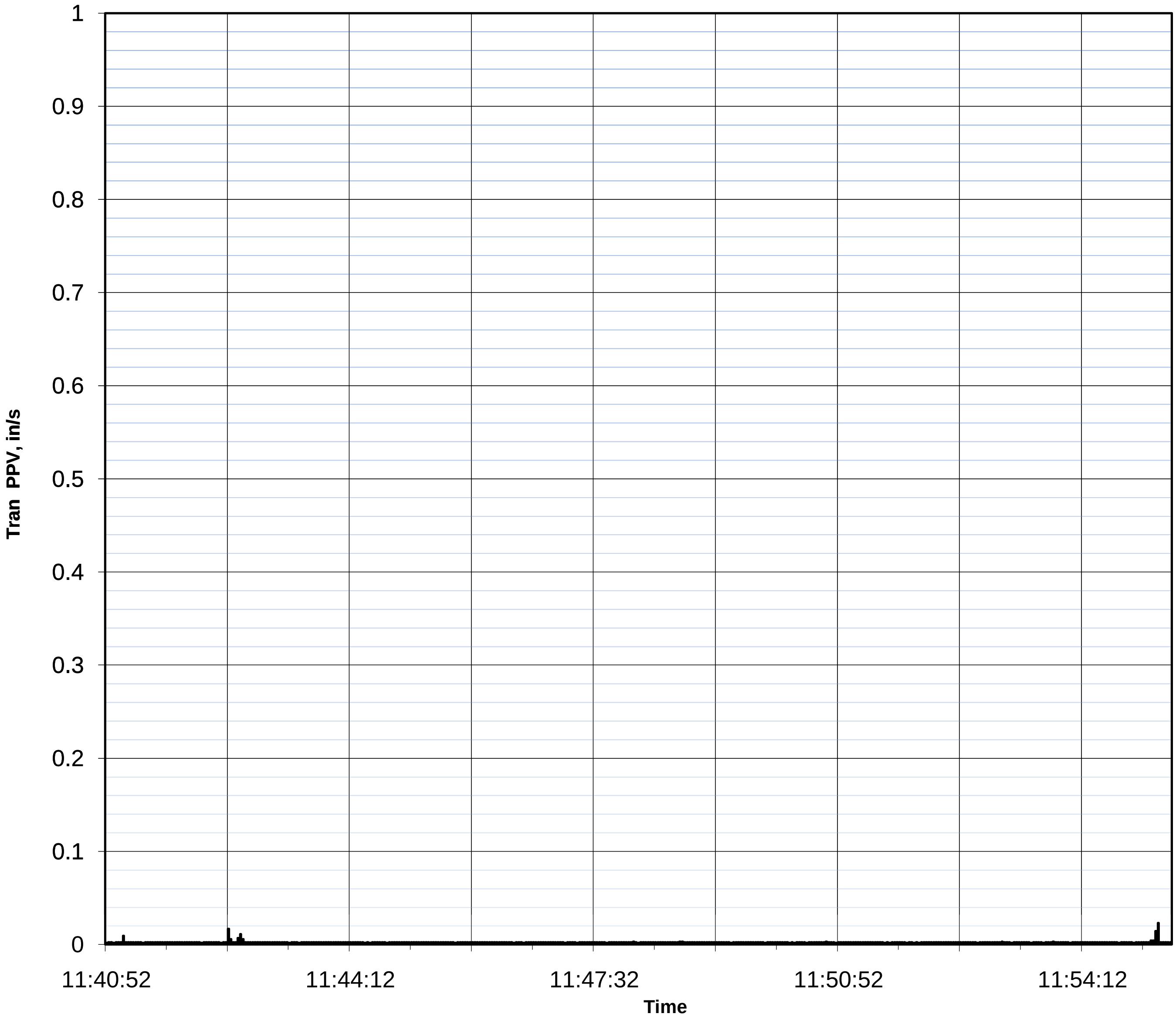
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Long PPV



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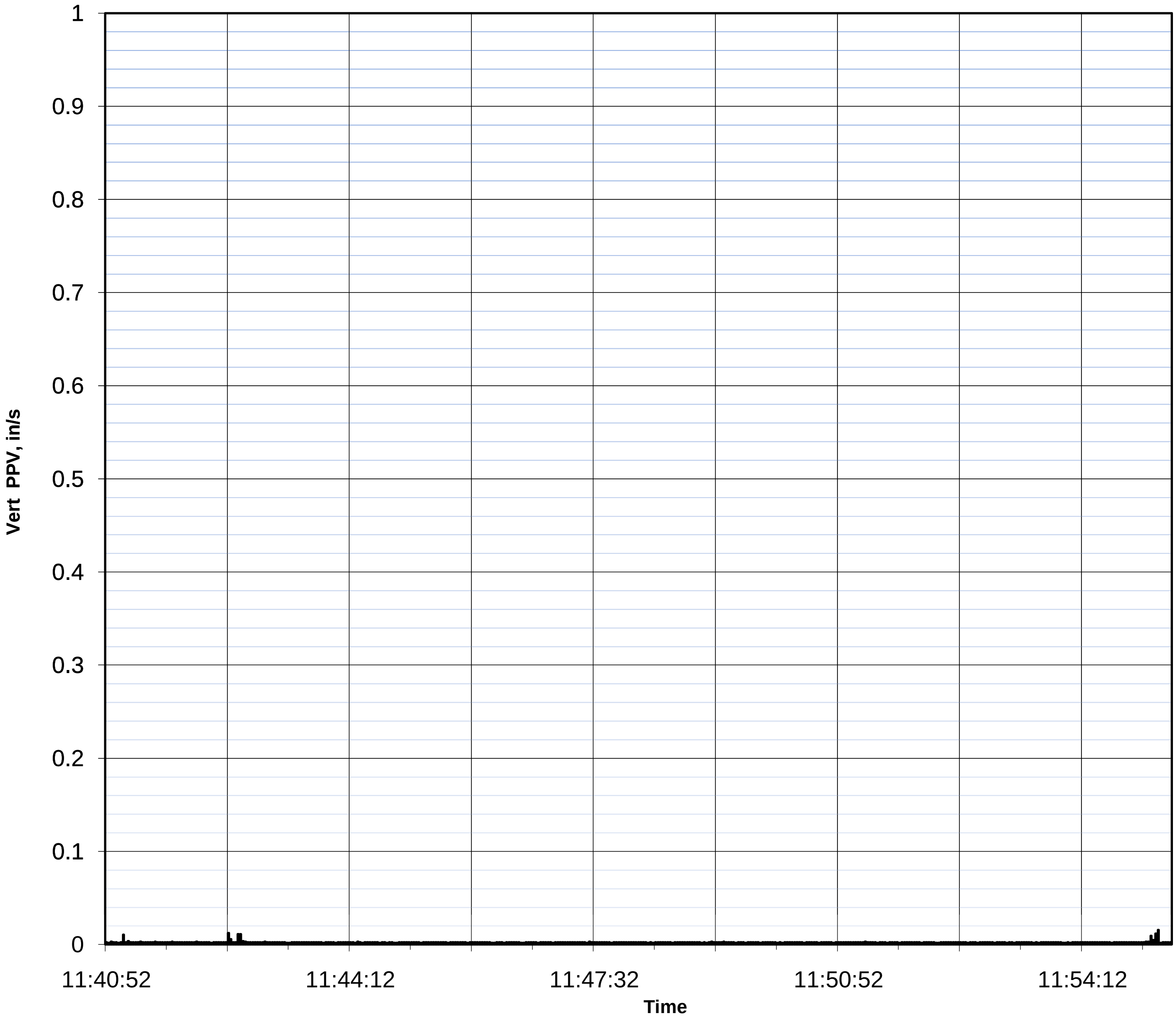
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Tran PPV



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Vert Peak Date:	3/18/10
Vert PPV (in/sec):	0.016

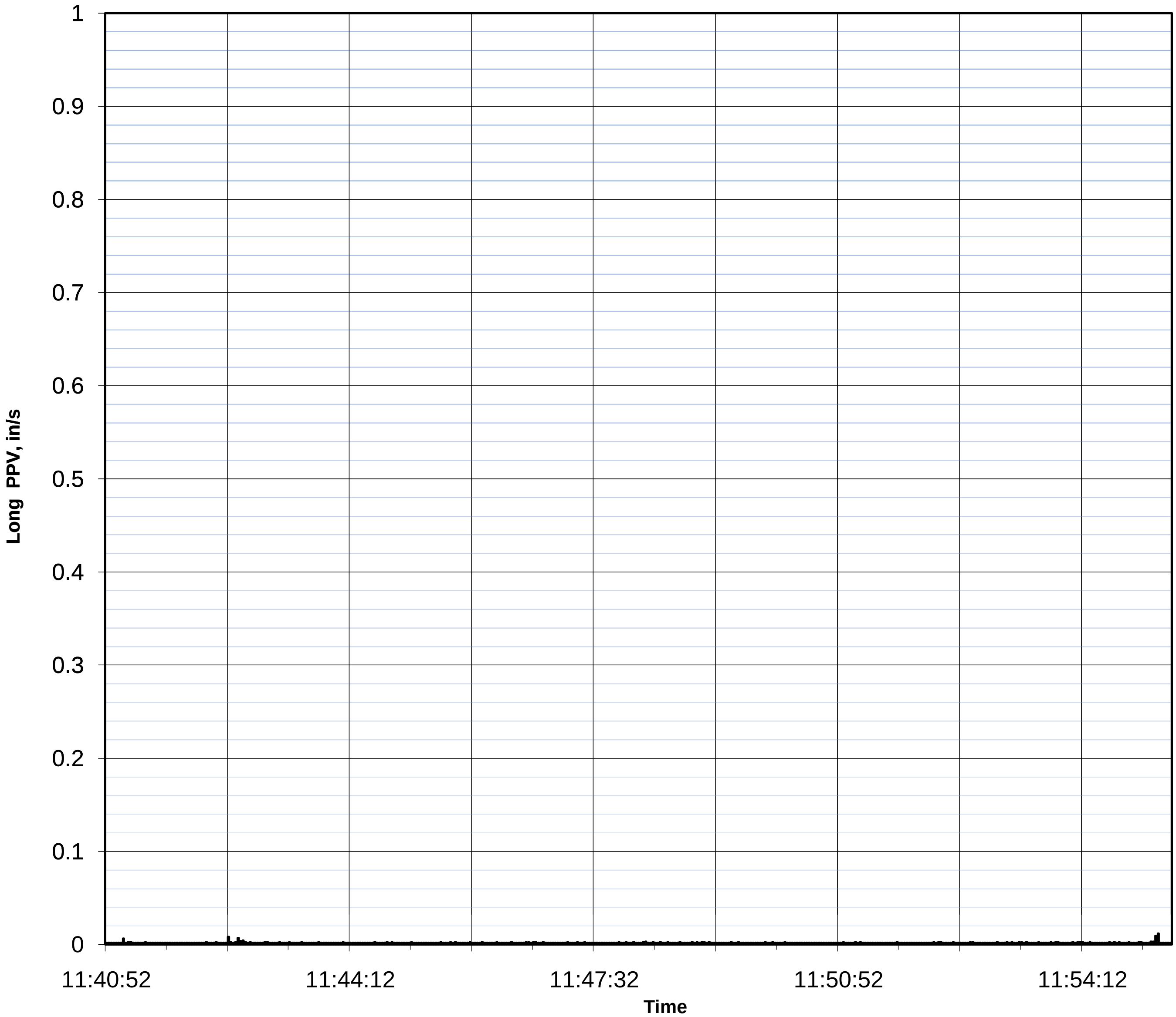
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

YKE Yogi Kwong Engineers, LLC

Vert PPV



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Histogram Start Date:	3/18/10
Histogram Stop Time:	11:55:24
Histogram Stop Date:	3/18/10
Number of Intervals:	437
Long Peak Time:	11:55:14
Long Peak Date:	3/18/10
Long PPV (in/sec):	0.012

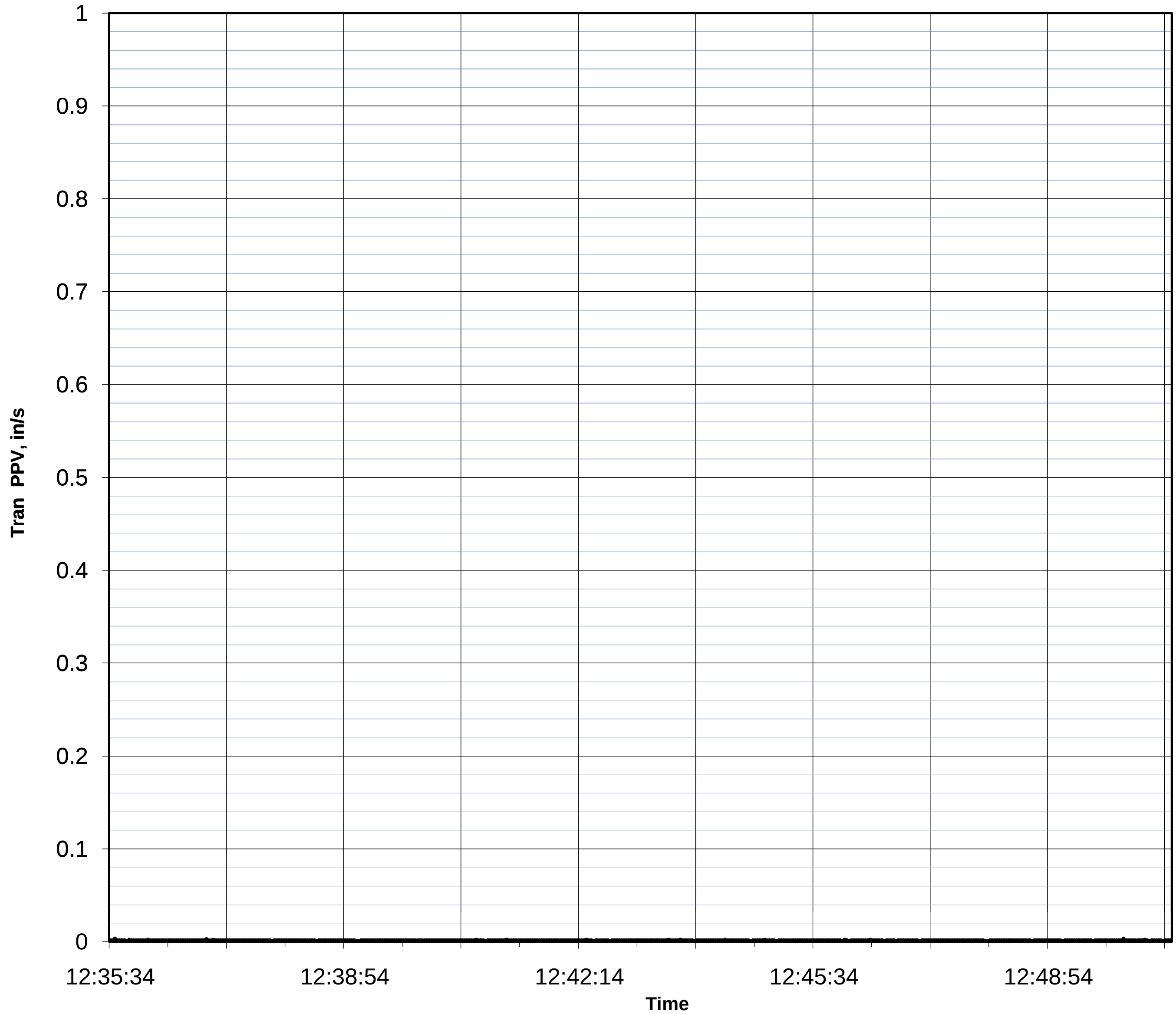
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Long PPV



Location:	Site 4
Histogram Start Time:	12:35:34
Histogram Start Date:	3/18/10
Histogram Stop Time:	12:50:38
Histogram Stop Date:	3/18/10
Number of Intervals:	453
Tran Peak Time:	12:35:38
Tran Peak Date:	3/18/10
Tran PPV (in/sec):	0.004

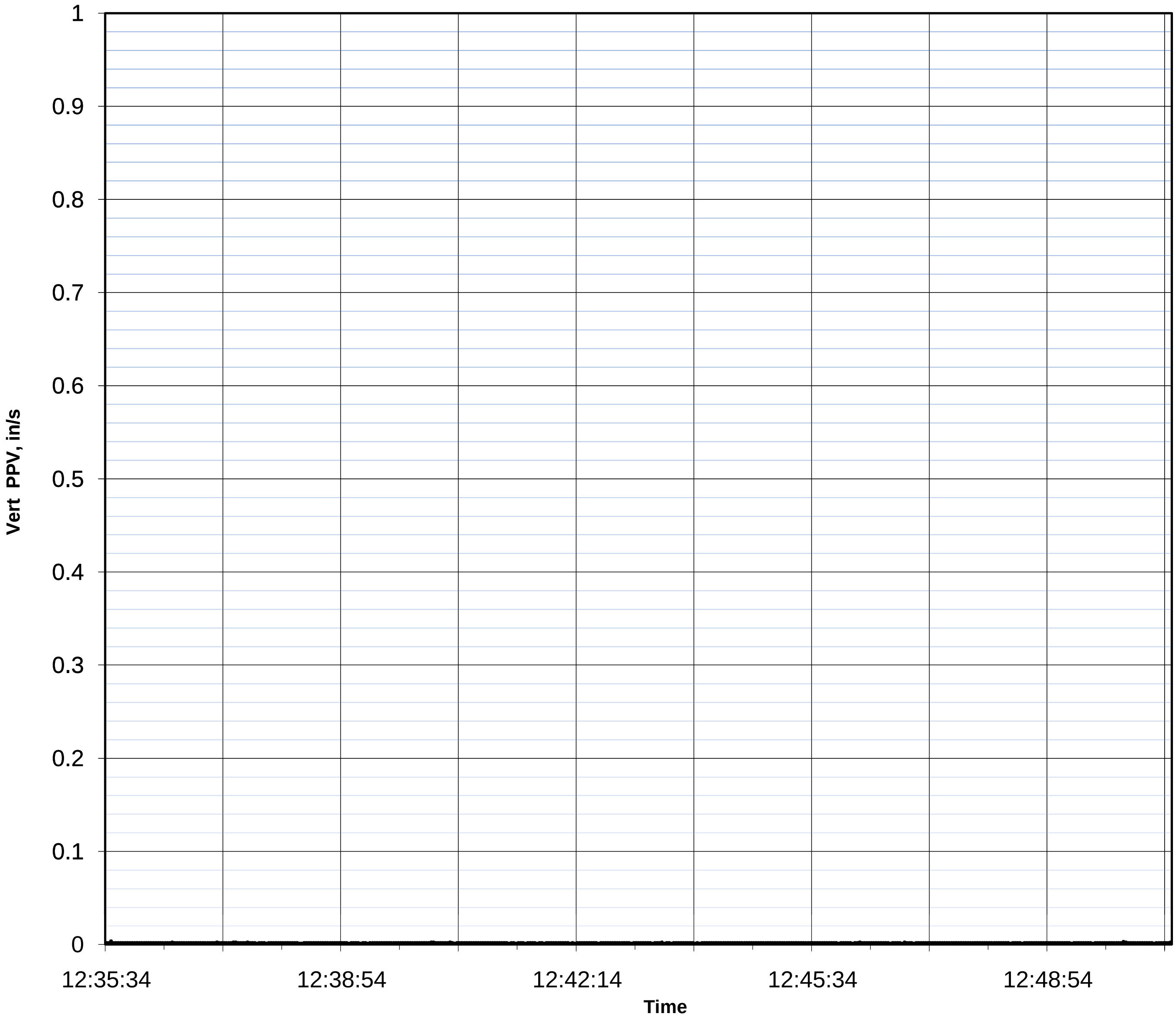
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

YKE Yogi Kwong Engineers, LLC

Tran PPV



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Histogram Start Time:	12:35:34
Histogram Start Date:	3/18/10
Histogram Stop Time:	12:50:38
Histogram Stop Date:	3/18/10
Number of Intervals:	453
Vert Peak Time:	12:35:38
Vert Peak Date:	3/18/10
Vert PPV (in/sec):	0.004

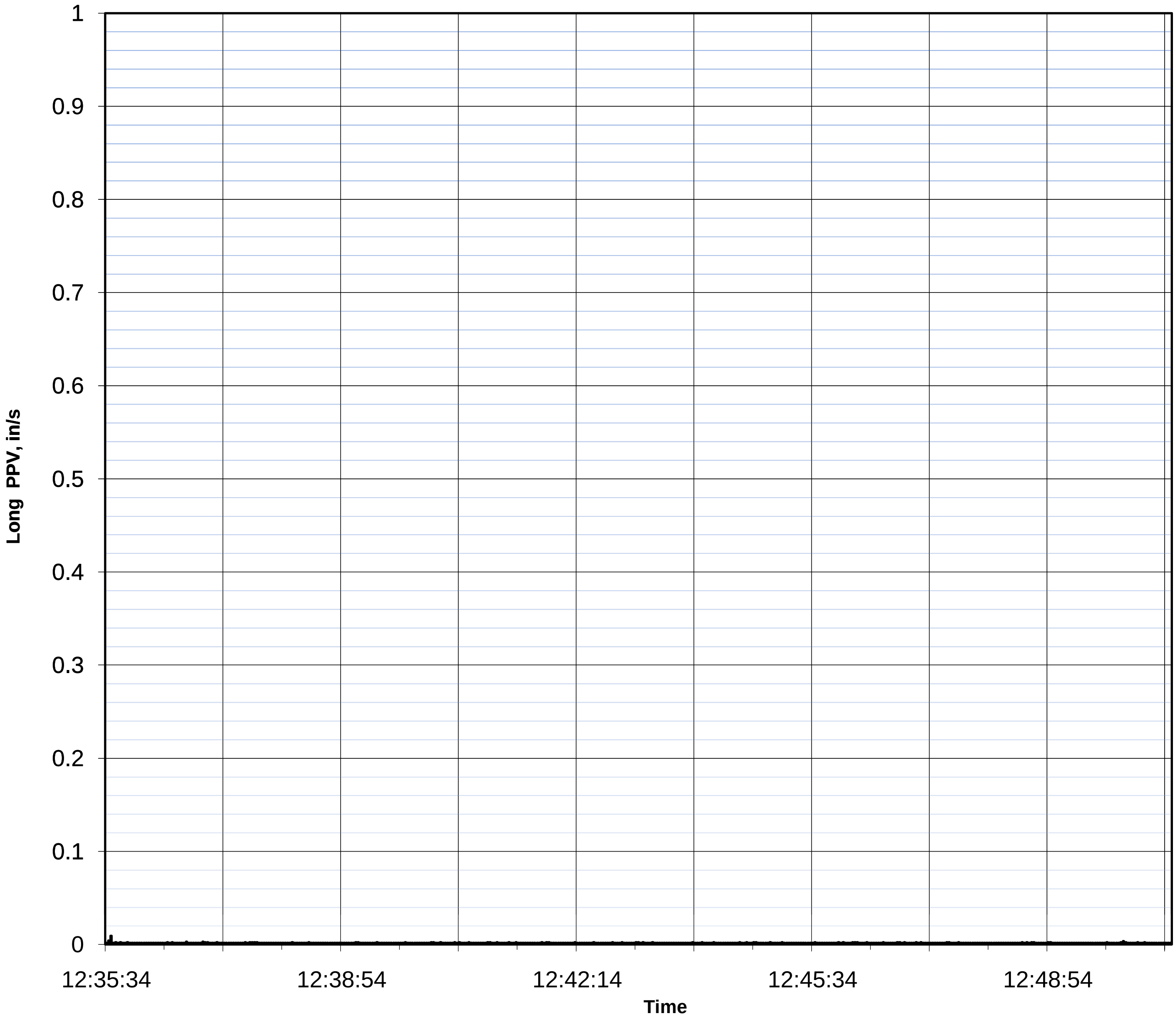
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Vert PPV



Location:	Site 4
Histogram Start Time:	12:35:34
Histogram Start Date:	3/18/10
Histogram Stop Time:	12:50:38
Histogram Stop Date:	3/18/10
Number of Intervals:	453
Long Peak Time:	12:35:38
Long Peak Date:	3/18/10
Long PPV (in/sec):	0.009

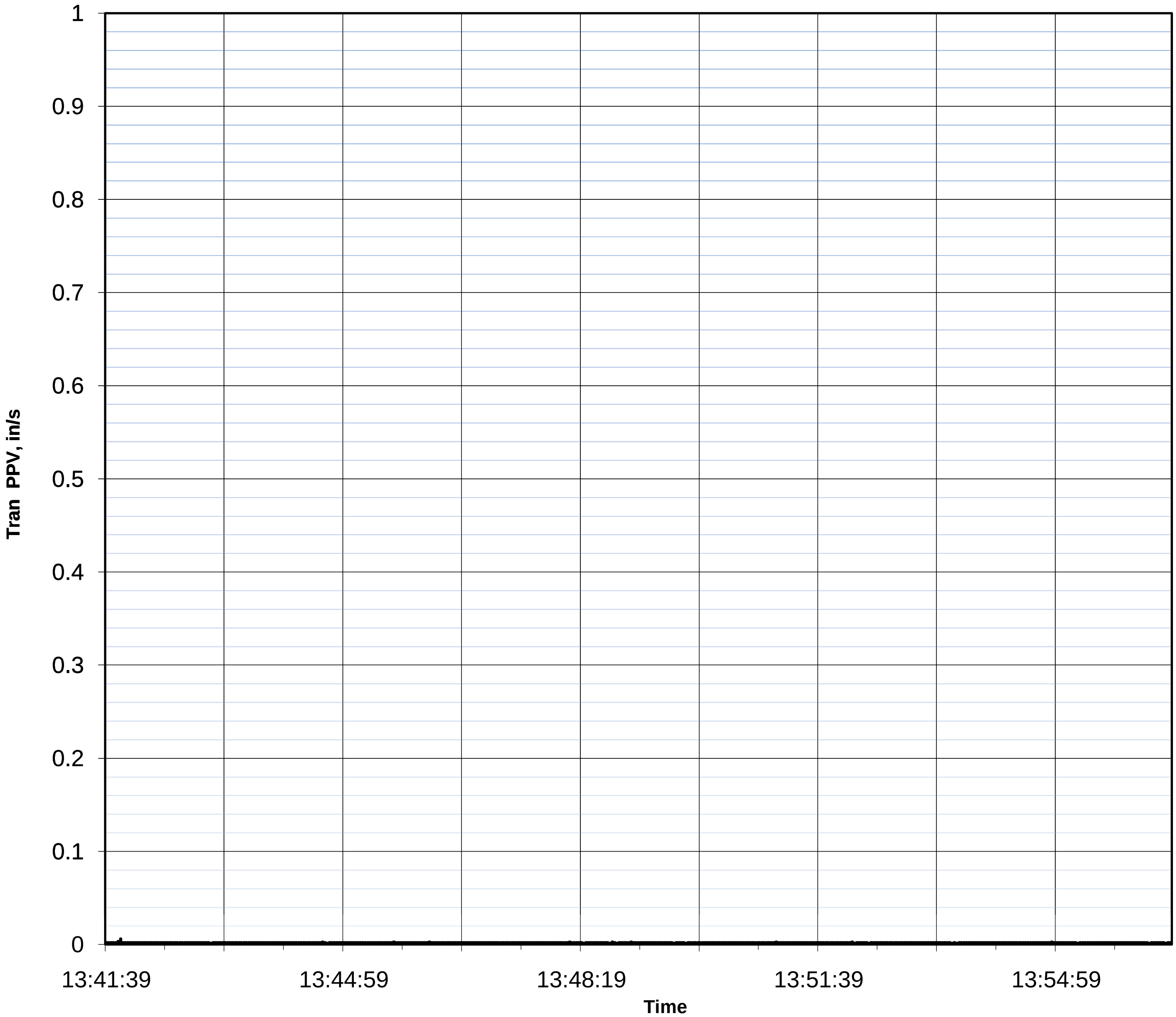
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Long PPV



Location:	Site 5
Histogram Start Time:	13:41:39
Histogram Start Date:	3/18/10
Histogram Stop Time:	13:56:35
Histogram Stop Date:	3/18/10
Number of Intervals:	449
Tran Peak Time:	13:41:51
Tran Peak Date:	3/18/10
Tran PPV (in/sec):	0.006

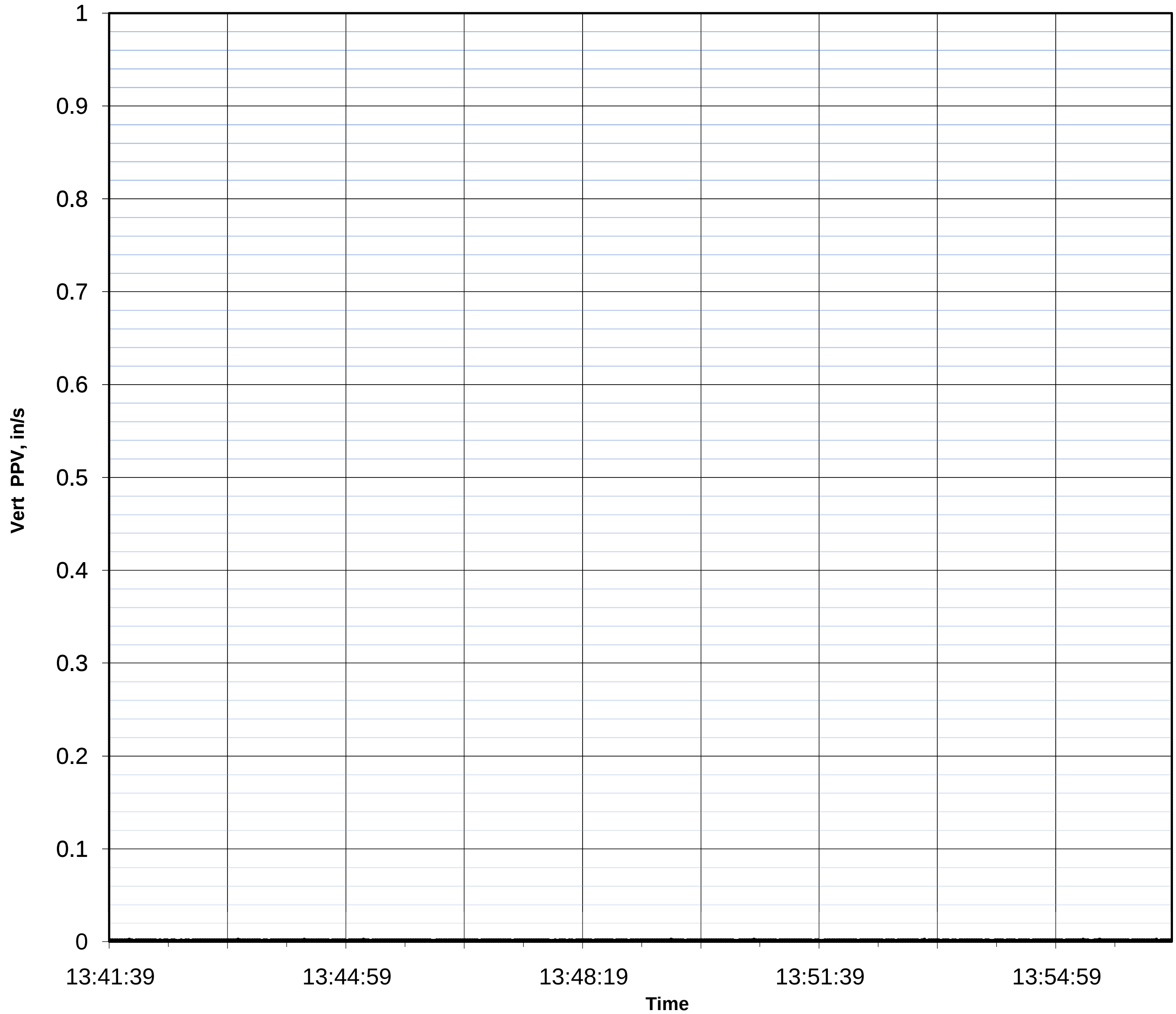
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Tran PPV



Location:	Site 5
Histogram Start Time:	13:41:39
Histogram Start Date:	3/18/10
Histogram Stop Time:	13:56:35
Histogram Stop Date:	3/18/10
Number of Intervals:	449
Vert Peak Time:	13:41:55
Vert Peak Date:	3/18/10
Vert PPV (in/sec):	0.003

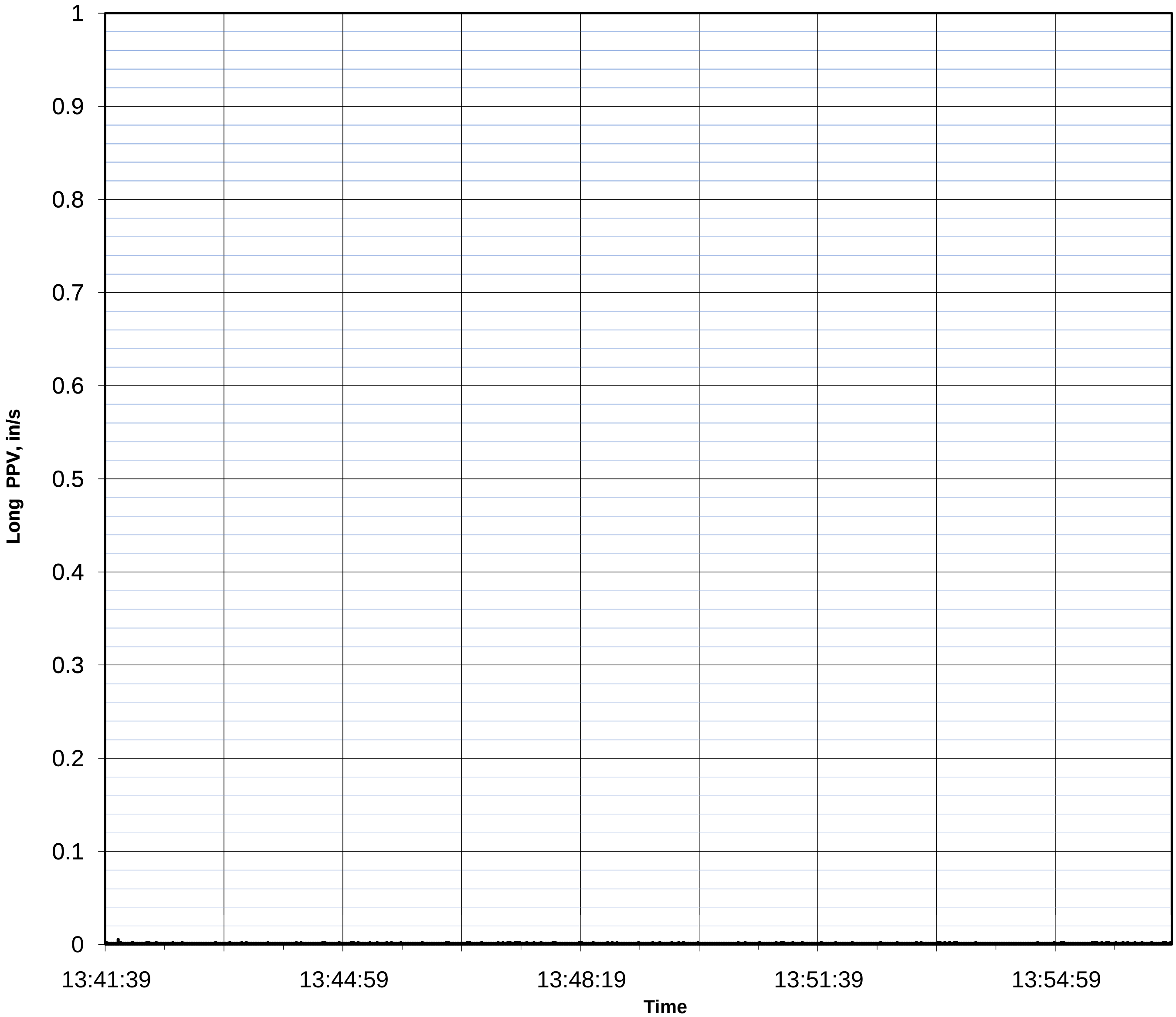
Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

Yogi Kwong Engineers, LLC

Vert PPV



Location:	Site 5
Histogram Start Time:	13:41:39
Histogram Start Date:	3/18/10
Histogram Stop Time:	13:56:35
Histogram Stop Date:	3/18/10
Number of Intervals:	449
Long Peak Time:	13:41:49
Long Peak Date:	3/18/10
Long PPV (in/sec):	0.006

Project: Kaneohe / Kailua Force Main No. 2

Kaneohe WWPS to Kailua WWPS, Oahu, Hawaii

Project Number: 06040

YKE Yogi Kwong Engineers, LLC

Long PPV

Appendix N

Construction Traffic Impact Report Kaneohe to Kailua Conveyance and Treatment Facilities Gravity Tunnel Alternative

Wilson Okamoto Corporation

December 2010

Construction Traffic Impact Report

Kaneohe to Kailua Conveyance & Treatment Facility

Gravity Tunnel Alternative

Prepared For

City and County of Honolulu

Prepared By

Wilson Okamoto Corporation

December 2010

CONSTRUCTION TRAFFIC IMPACT REPORT

FOR THE

KANEOHE TO KAILUA

CONVEYANCE & TREATMENT FACILITIES

Gravity Tunnel Alternative

Prepared for:

City and County of Honolulu
650 S. King Street
Honolulu, HI 96813

Prepared by:

Wilson Okamoto Corporation
1907 South Beretania Street, Suite 400
Honolulu, Hawaii 96826
WOC Ref: 7801-04

December 2010

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I. INTRODUCTION

A. Purpose of Study

The purpose of this study is to identify and assess the traffic impacts resulting from construction truck traffic associated with the proposed gravity tunnel alternative for the Kaneohe to Kailua Conveyance & Treatment Facility project. The proposed gravity tunnel would connect the existing Kaneohe Wastewater Pre-Treatment Facility (WWPTF) and Kailua Regional Wastewater Treatment Plant (WWTP) on the island of Oahu.

B. Scope of Study

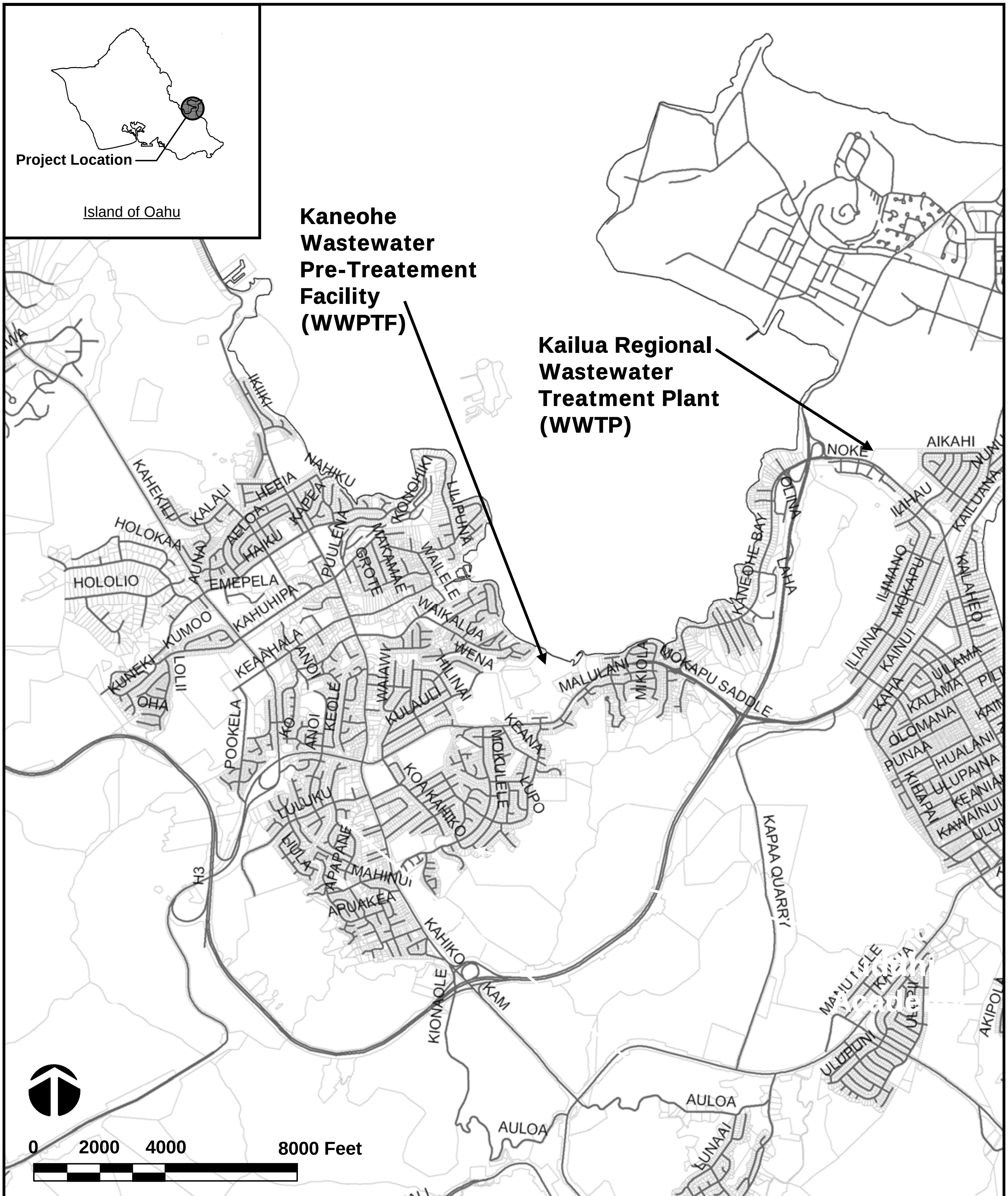
This report presents the findings and conclusions of the traffic study, the scope of which includes:

1. Description of the proposed project.
2. Evaluation of baseline roadway and traffic operations in the vicinity.
3. Superimposing construction-related truck traffic over baseline traffic conditions.
4. The identification and analysis of traffic impacts resulting from construction-related truck traffic.
5. Recommendations of improvements, if appropriate, that would mitigate the traffic impacts resulting from construction-related truck traffic.

II. PROJECT DESCRIPTION

A. Location

The existing Kaneohe Wastewater Pre-Treatment Facility (WWPTF) is located at the eastern terminus of Kulauli Street north of Kaneohe Bay Drive in Kaneohe (see Figure 1). Access to the WWPTF facility from Kaneohe Bay Drive is provided via Puohala Street and Kulauli Street. In Kailua, the existing Kailua Regional Wastewater Treatment Plant (WWTP) is located adjacent to Kaneohe Bay Drive east of the Interstate H-3 Freeway. Access to the WWTP facility from Kaneohe Bay Drive is provided via an existing driveway off that roadway.



WILSON OKAMOTO CORPORATION ENGINEERS - PLANNERS	KANEOHE TO KAILUA WASTEWATER CONVEYANCE & TREATMENT FACILITIES LOCATION MAP	FIGURE 1

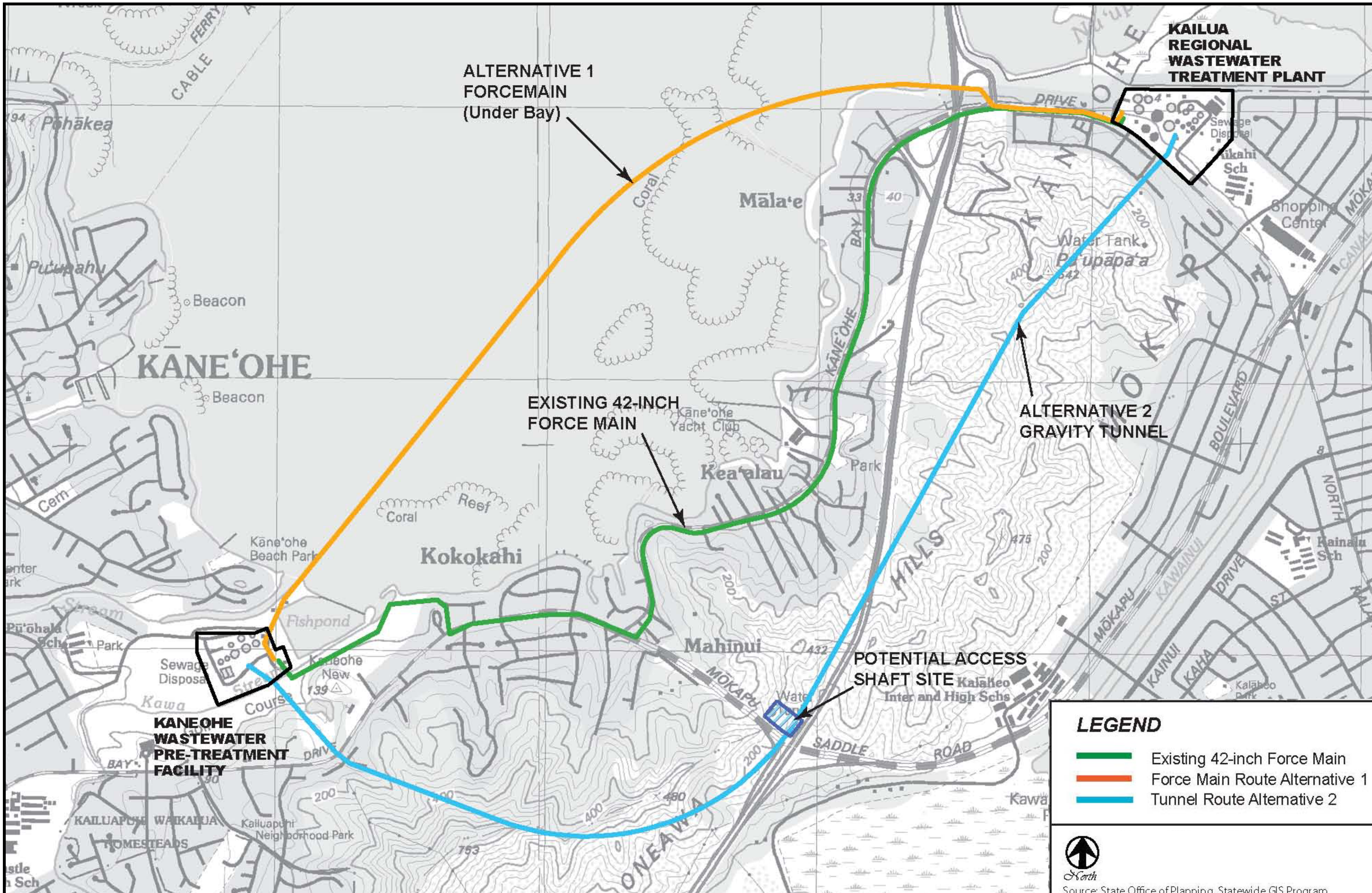
B. Project Characteristics

Currently, there is a force main that conveys wastewater between the Kaneohe Wastewater Pre-Treatment Facility (WWPTF) and the Kailua Regional Wastewater Treatment Plan (WWTP). The City and County of Honolulu plans to construct either an additional force main or a gravity-flow sewer tunnel to supplement this existing force main to provide additional capacity during peak flow conditions, as well as, provide an emergency back-up system. A traffic study for the additional force main alternative is being addressed by a separate study. This traffic report focuses on the gravity-flow sewer alternative. The gravity tunnel alternative entails the construction of an approximately three-mile long tunnel north of Kaneohe Bay Drive (see Figure 2). During construction, the tunnel will be accessed via vertical shafts at either end with the excavated material removed and hauled to the Waimanalo Gulch Landfill from both ends. On the Kaneohe end of the tunnel, construction related-truck traffic hauling excavated material to the landfill is expected to utilize Kulauli Street, Puohala Street, and Kaneohe Bay Drive to access the Interstate H-3 Freeway (see Figure 3). On the Kailua end of the tunnel, construction-related truck traffic is expected to utilize Kaneohe Bay Drive to access the Interstate H-3 Freeway (see Figure 4). All construction-related truck traffic is expected to utilize the Interstate H-3 Freeway and the Interstate H-1 Freeway to travel between the Waimanalo Gulch Landfill near Kapolei and project sites.

III. EXISTING TRAFFIC CONDITIONS

A. Area Roadway System

Access to the Kaneohe WWPTF is provided via Kulauli Street, a two-lane, two-way roadway generally oriented in the east-west direction. Southwest of the WWPTF, Kulauli Street intersects Puohala Street. At this unsignalized intersection, the Kulauli Street approaches have one stop-controlled lane that serves all traffic movements. Puohala Street is a two-lane, two-way roadway generally oriented in the north-south direction. At the intersection with Kulauli Street, both approaches of Puohala Street have one lane that serves all traffic movements.



KANEOHE TO KAILUA WASTEWATER CONVEYANCE & TREATMENT FACILITIES

PROJECT SITE PLAN

FIGURE 2

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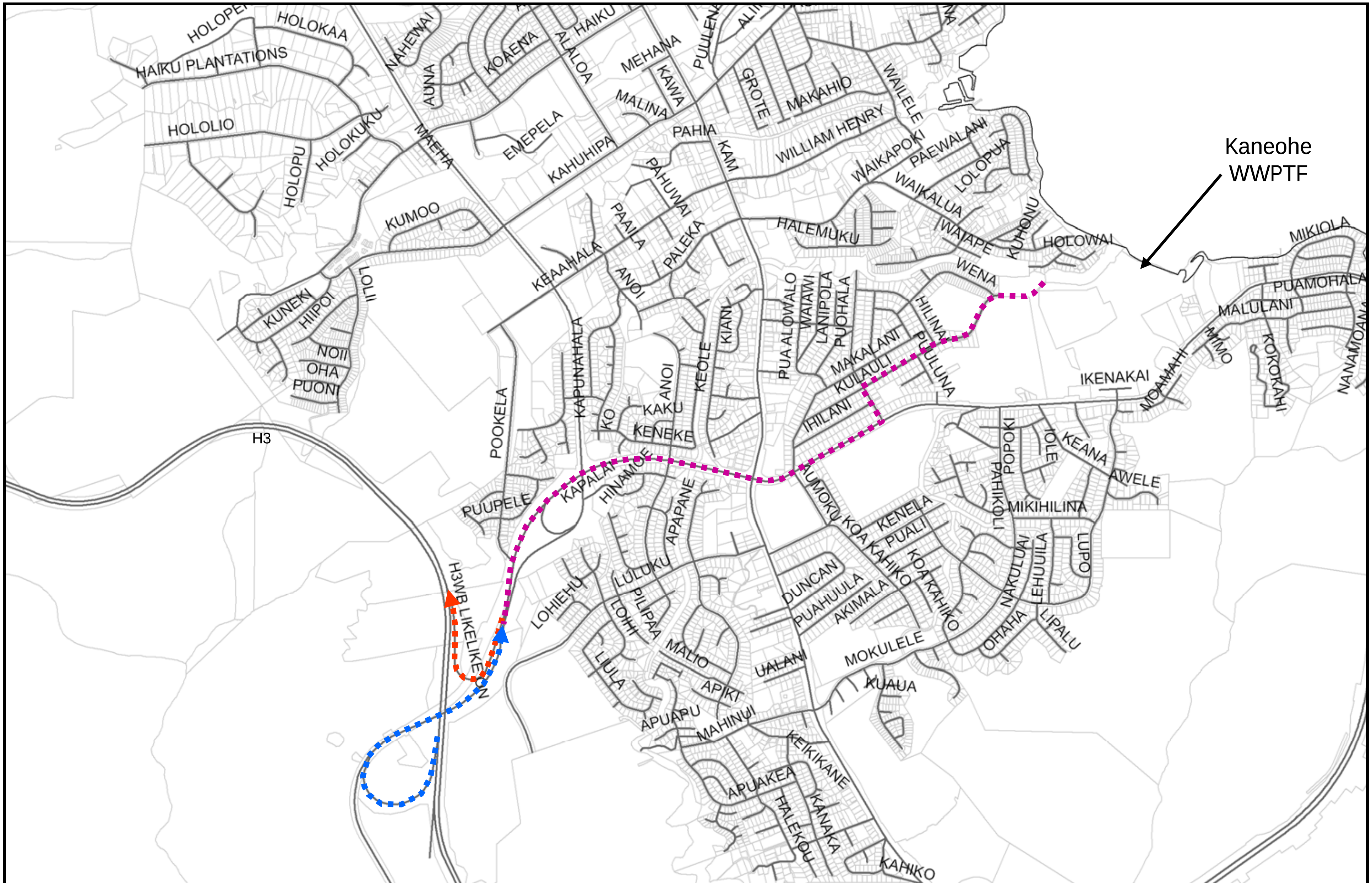

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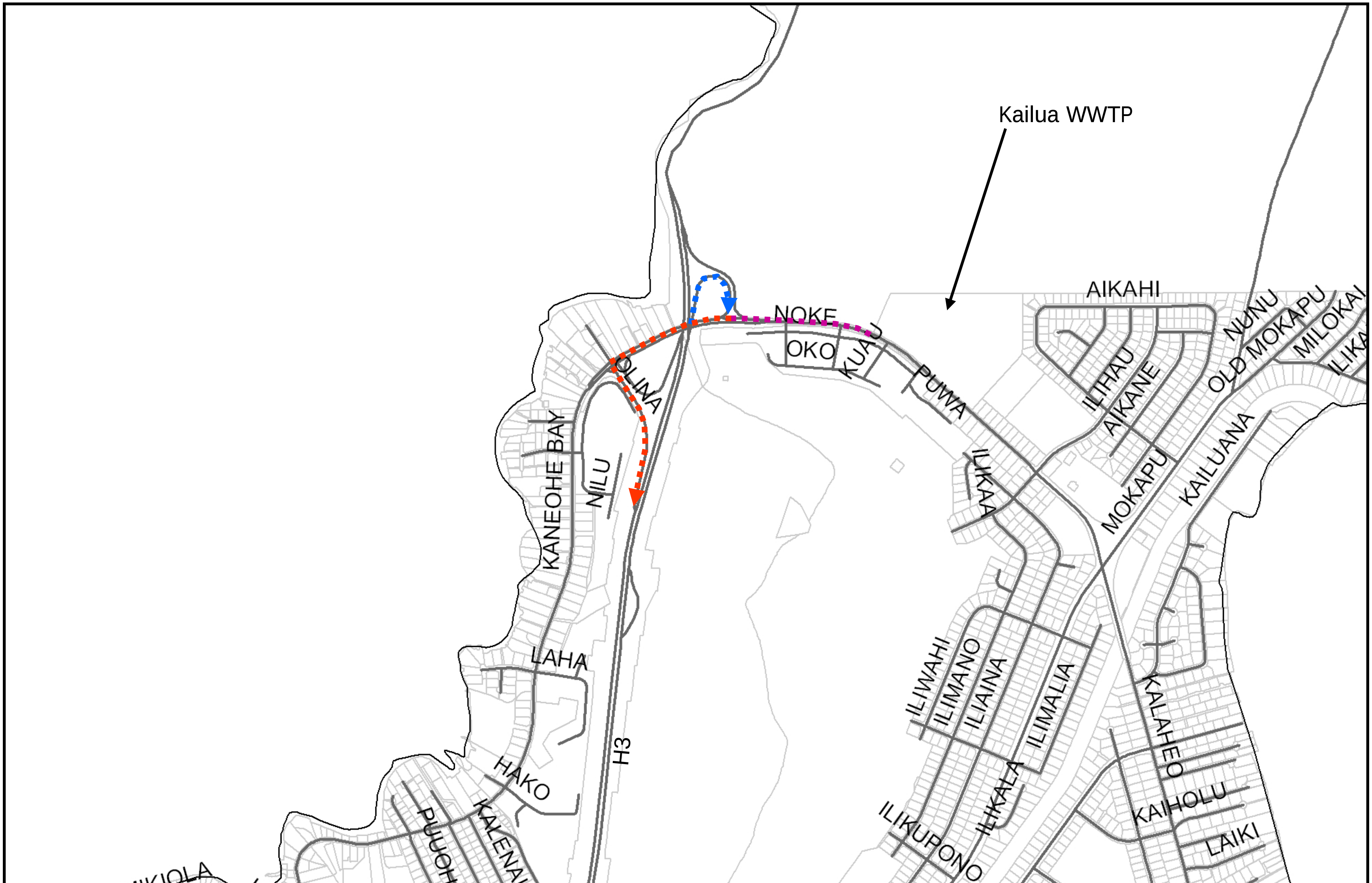
KANEOHE TO KAILUA WASTEWATER CONVEYANCE & TREATMENT FACILITIES

KANEOHE WWPTF CONSTRUCTION TRUCK TRAFFIC ROUTE

FIGURE 3



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KANEOHE TO KAILUA WASTEWATER CONVEYANCE & TREATMENT FACILITIES

KAILUA WWTP CONSTRUCTION TRUCK TRAFFIC ROUTE

FIGURE 4

Southeast of the intersection with Kulauli Street, Puohala Street intersects Kaneohe Bay Drive. At this signalized T-intersection, the Puohala Street approach has one lane that serves left-turn and right-turn traffic movements. In the vicinity of the Kaneohe WWPTF, Kaneohe Bay Drive is a predominantly four-lane, two-way divided roadway generally oriented in the east-west direction. At the intersection with Puohala Street, the eastbound approach of Kaneohe Bay Drive has an exclusive left-turn lane and two through lanes while the westbound approach has two lanes that serve through and right-turn traffic movements.

From the intersection with Puohala Street, Kaneohe Bay Drive heads eastward towards Mokapu Saddle Road then turns northward towards the Kailua Regional WWTP. In the vicinity of the WWTP, Kaneohe Bay Drive is a predominantly two-lane, two-way divided roadway generally oriented in the east-west direction.

B. Traffic Volumes and Conditions

1. General

a. Field Investigation

Although construction activities are expected to extend throughout the day and night, truck traffic is expected to be restricted to daytime work hours, typically 9:00 AM to 3:00 PM. As such, a field investigation was conducted on November 23, 2010 during the mid-day peak hours of 11:00 AM and 1:00 PM when construction-related truck traffic is expected to be utilizing the surrounding roadways. The field investigation consisted of manual turning movement count surveys and traffic flow assessments at the intersections of Puohala Street with Kulauli Street and Kaneohe Bay Drive. In addition, 24-hour mechanical traffic count data was collected along Kulauli Street, Puohala Street, and Kaneohe Bay Drive in the vicinity of the Kaneohe WWPTF, as well as, Kaneohe Bay Drive in the vicinity of the Kailua Regional WWTP. Appendix A includes the existing traffic count data.

b. Capacity Analysis Methodology

The highway capacity analysis performed in this study is based upon procedures presented in the "Highway Capacity Manual", Transportation Research Board, 2000, and the "Highway Capacity Software", developed by the Federal Highway Administration. The analysis is based on the concept of Level of Service (LOS).

LOS is a quantitative and qualitative assessment of traffic operations. Levels of Service are defined by LOS "A" through "F"; LOS "A" representing ideal or free-flow traffic operating conditions and LOS "F" representing unacceptable or potentially congested traffic operating conditions.

"Volume-to-Capacity" (v/c) ratio is another measure indicating the relative traffic demand to the roadway carrying capacity. A v/c ratio of one (1.00) indicates that the roadway is operating at or near capacity. A v/c ratio of greater than 1.00 generally indicates that the traffic demand exceeds the road's carrying capacity. The LOS definitions are included in Appendix B.

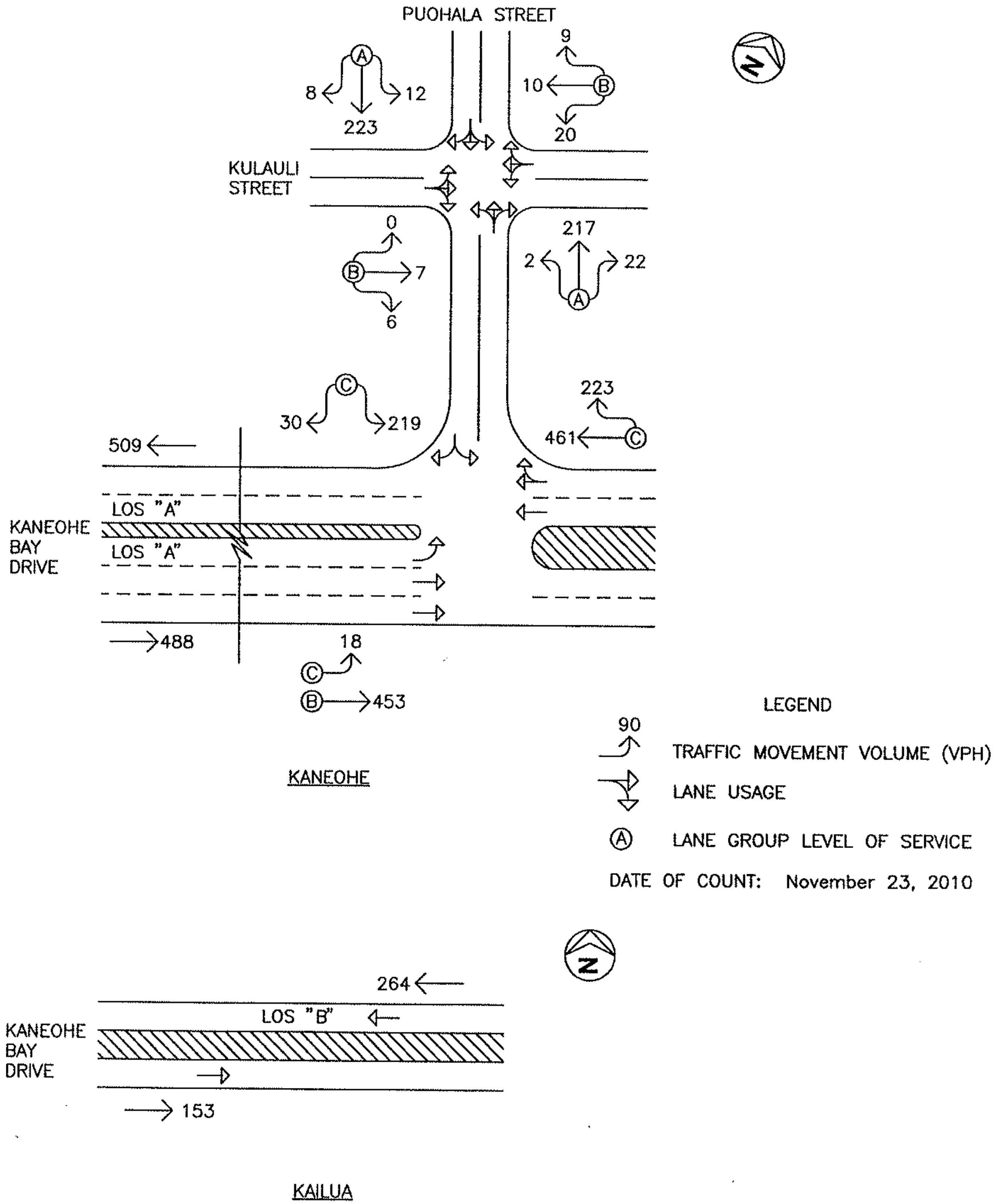
2. Baseline Peak Hour Traffic

a. General

Figure 5 shows the baseline midday peak period traffic volumes and traffic operating conditions. The mid-day peak hour of traffic generally occurs between the hours of 11:45 AM and 12:45 PM. The analysis is based on this mid-day peak period to identify the traffic impacts resulting from the anticipated construction-related truck traffic. LOS calculations are included in Appendix C.

b. Puohala Street and Kulauli Street

At the intersection with Kulauli Street, Puohala Street carries 241 vehicles northbound and 243 vehicles southbound during the mid-day peak period with both approaches operating at LOS "A" during



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KANEOHE TO KAILUA WASTEWATER CONVEYANCE & TREATMENT FACILITIES

BASELINE MID-DAY PEAK HOUR OF TRAFFIC

FIGURE 5

this period. The Kulauli Street approaches of this intersection carry 13 vehicles eastbound and 39 vehicles westbound during the mid-day peak period. During this peak period, both approaches of Kulauli Street operate at LOS "B."

c. Puohala Street and Kaneohe Bay Drive

At the intersection with Kaneohe Bay Drive, Puohala Street carries 249 vehicles southbound during the mid-day peak hour of traffic and operates at LOS "C." The Kaneohe Bay Drive approaches of this intersection carry 471 vehicles eastbound and 684 vehicles westbound during the mid-day peak period. The eastbound left-turn traffic movement operates at LOS "A" during this peak period while the eastbound and westbound through movements operate at LOS "B."

West of the intersection with Puohala Street, Kaneohe Bay Drive carries 488 vehicles eastbound and 509 vehicles westbound during the mid-day peak period. Both directions of traffic along this roadway operate at LOS "A" during this peak period.

d. Kaneohe Bay Drive Near Kailua Regional WWTP

West of the Kailua Regional WWTP, Kaneohe Bay Drive carries 153 vehicles eastbound and 264 vehicles westbound during the mid-day peak period. During this period, Kaneohe Bay Drive operates at LOS "B."

IV. PROJECTED TRAFFIC CONDITIONS

A. Construction-Related Truck Traffic

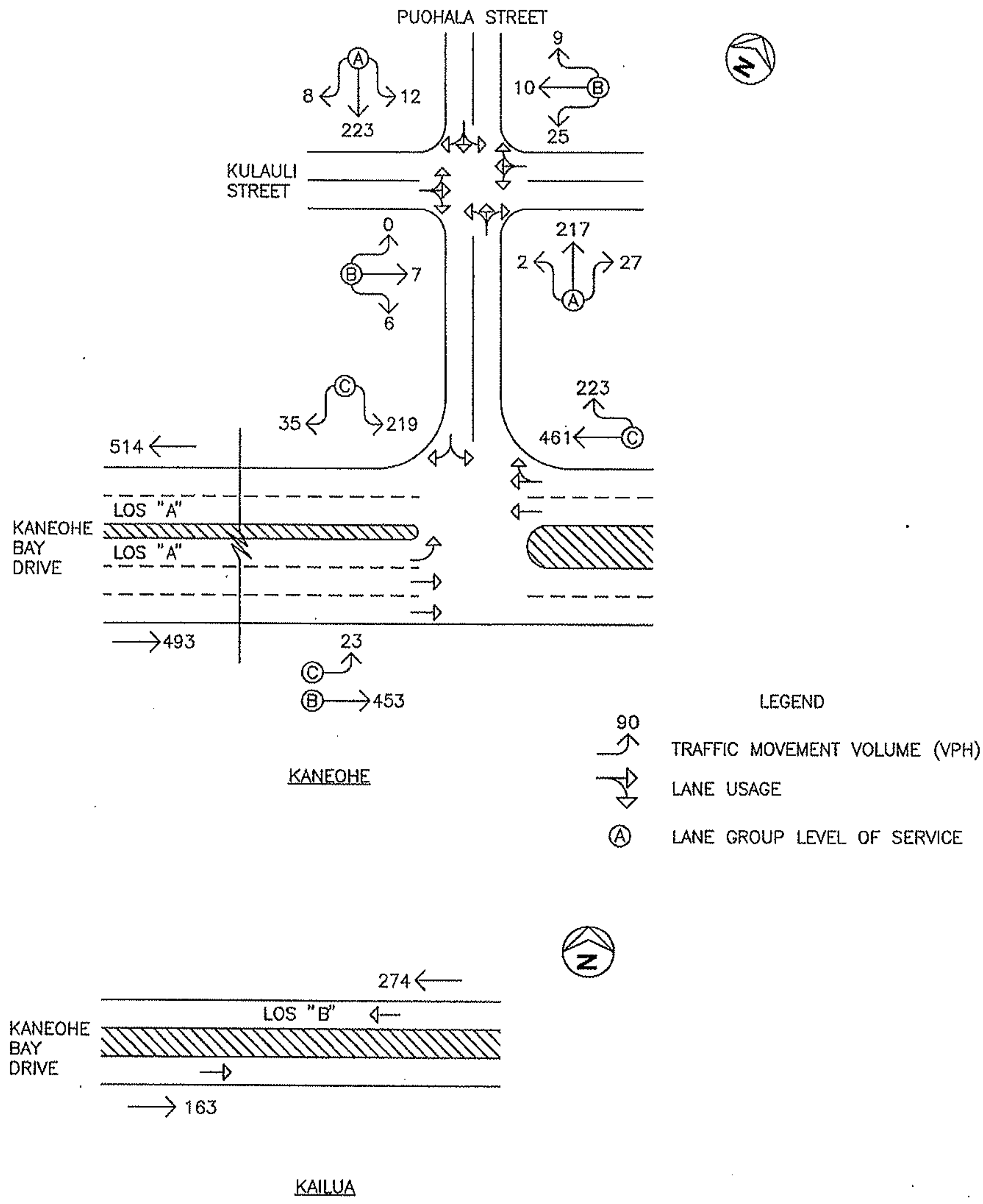
The anticipated volume of construction-related truck traffic is based upon projections prepared by Jacobs Associates (see Appendix D). The proposed gravity tunnel is expected constructed over 32 months is four major phases. Of these phases, construction-related truck traffic is expected to be highest during the tunnel excavation phase. As such, the traffic analyses are conservatively based upon the average and maximum truck traffic projections during this phase.

As previously discussed, construction truck traffic is expected to be restricted to daytime work hours although construction activities may extend throughout the day and night. These work hours are expected to occur between 9:00 AM and 3:00 PM, resulting in approximately 6 hours of the day during which truck traffic is expected to access both ends of the tunnel. As such, approximately 10 trucks per hour (5 entering and 5 exiting) are anticipated to access the Kaneohe WWPTF on average with a maximum of 14 trucks anticipated per hour (7 entering and 7 exiting). Entering truck traffic is assumed to head eastbound on Kaneohe Bay Drive from the Interstate H-3 Freeway, turn left onto Puohala Street, and turn right onto Kulauli Street while exiting truck traffic is assumed to head westbound on Kulauli Street, turn left onto Puohala Street, and turn right onto Kaneohe Bay Drive to access the Interstate H-3 Freeway.

At the Kailua Regional WWTP, approximately 20 trucks per hour are anticipated on average (10 entering and 10 exiting) with a maximum of approximately 34 trucks per hour (17 entering and 17 exiting). Entering truck traffic is expected to head eastbound on Kaneohe Bay Drive from the Interstate H-3 Freeway and turn left into the WWTP while exiting truck traffic is expected to turn right from the WWTP and head eastbound on Kaneohe Bay Drive to access the Interstate H-3 Freeway.

B. Total Traffic Volumes With Construction-Related Truck Traffic

The cumulative mid-day peak hour traffic conditions with construction-related truck traffic utilizing the surrounding roadways is shown in Figures 6 and 7, and summarized in Tables 1 and 2. The cumulative volumes consist of the average and maximum volumes of construction-related truck traffic superimposed over baseline traffic demands. The baseline operating conditions are provided for comparison purposes. LOS calculations are included in Appendices D and E.



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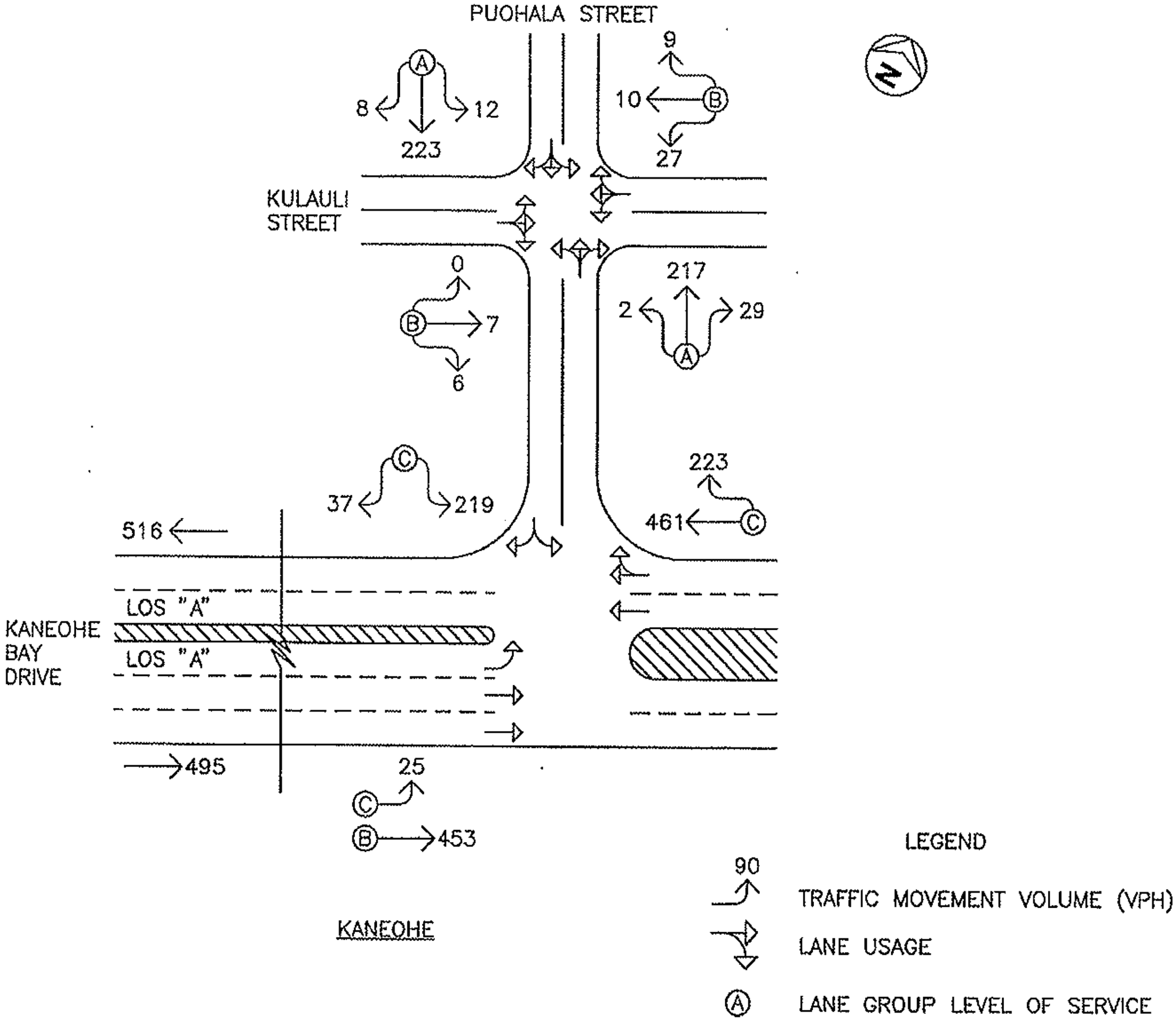
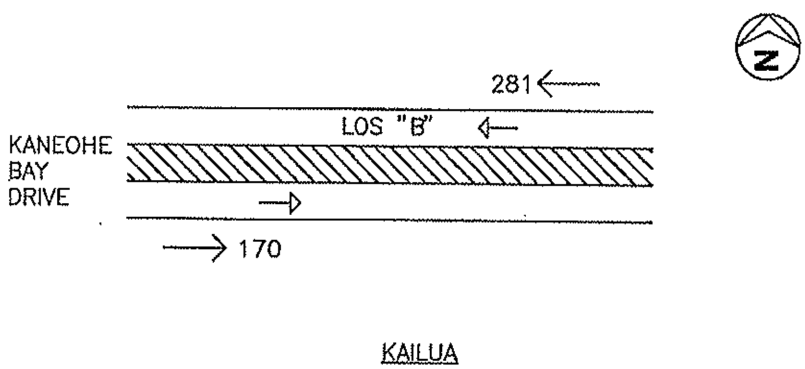
KANEOHE TO KAILUA WASTEWATER CONVEYANCE & TREATMENT FACILITIES

MID-DAY PEAK HOUR OF TRAFFIC WITH CONSTRUCTION TRAFFIC (AVERAGE)

FIGURE 6





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KANEOHE TO KAILUA WASTEWATER CONVEYANCE & TREATMENT FACILITIES

MID-DAY PEAK HOUR OF TRAFFIC WITH CONSTRUCTION TRAFFIC (MAXIMUM)

FIGURE 7

Table 1: Baseline and Projected Intersection LOS Traffic Operating Conditions

Intersection	Traffic Movement		Baseline	w/ Ave	w/ Max
Puohala St/ Kulauli St	Eastbound	LT-TH-RT	B	B	B
	Westbound	LT-TH-RT	B	B	B
	Northbound	LT-TH-RT	A	A	A
	Southbound	LT-TH-RT	A	A	A
Puohala St/ Kaneohe Bay Dr	Eastbound	LT	A	A	A
		TH	B	B	B
	Westbound	TH-RT	B	B	B
	Southbound	LT-RT	C	C	C

Table 2: Baseline and Projected Roadway LOS Traffic Operating Conditions

Intersection	Direction	Baseline	w/ Ave	w/ Max
Kaneohe Bay Dr (west of Puohala St)	Eastbound	A	A	A
	Westbound	A	A	A
Kaneohe Bay Dr (west of Kailua Regional WWTP)		B	B	B

Traffic operations with the average and maximum volume of construction-related truck traffic are expected to remain similar baseline conditions during the mid-day peak period. The critical traffic movements at the intersection of Puohala Street with Kulauli Street are expected to continue operating at LOS "B" or better while those at the intersection with Kaneohe Bay Drive are expected to continue operating at LOS "C" or better. Along Kaneohe Bay Drive, both directions of traffic west of Puohala Street are expected to continue operating at LOS "A" while the roadway is expected to continue operating at LOS "B" west of the Kailua Regional WWTP.

Although projected conditions with the addition of construction-related truck traffic along the surrounding roadways are expected to remain similar to baseline conditions, the project sites are in close proximity to residential and school uses. As such, a construction traffic management plan is recommended for the proposed project to minimize the impact of construction activities on these uses.

V. RECOMMENDATIONS

Based on the analysis of the traffic data, the following are the recommendations of this study associated with the implementation of the master plan for the Honpa Hongwanji Mission of Hawaii:

1. Ensure construction-related trucks are not staged off-site along the adjacent public roadways.

2. Ensure that queues at the Kaneohe Wastewater Pre-Treatment Facility and Kailua Regional Wastewater Treatment Plant do not extend onto the adjacent public roadways.

3. Restrict parking along Puohala Street and Kulauli Street along the proposed construction-related truck route during daytime work hours to maximize the roadway widths for passing and turning along the route.

4. Prepare a Construction Traffic Management Plan to minimize the impact of construction-related traffic on the adjacent residential and school uses, as well as, the surrounding roadways.

VI. CONCLUSION

The City and County of Honolulu plans to construct either an additional force main or a gravity-flow sewer tunnel to supplement the existing force main between the Kaneohe Wastewater Pre-Treatment Facility and Kailua Wastewater Treatment Plant. The gravity tunnel alternative entails the construction of an approximately three-mile long tunnel with access points at either end. The excavated material from the tunnel will be hauled to the Waimanalo Gulch Landfill near Kapolei from both ends of the tunnel. With the implementation of the aforementioned recommendations, the anticipated construction-related truck traffic is not expected to have a significant impact to the surrounding roadways since projected conditions are expected to remain similar to baseline conditions. However, due to the close proximity of residential and school uses, a construction traffic management plan is recommended for the proposed project to minimize the impact of construction activities on these uses.

APPENDIX A

BASELINE TRAFFIC COUNT DATA

Wilson Okamoto Corporation
1907 S. Beretania St., Suite 400
Honolulu, HI 96826

Description 1: Kaneohe Bay Drive
Description 2: Kaneohe
Description 3:

Site: 100000000000
Date: 11/23/2010
Tuesday

Daily Volume

Begin	EB		WB		Combined	
12:00 AM	-	-	-	-	-	-
12:15 AM	-		-		-	
12:30 AM	-		-		-	
12:45 AM	-		-		-	
1:00 AM	-	-	-	-	-	-
1:15 AM	-		-		-	
1:30 AM	-		-		-	
1:45 AM	-		-		-	
2:00 AM	-	-	-	-	-	-
2:15 AM	-		-		-	
2:30 AM	-		-		-	
2:45 AM	-		-		-	
3:00 AM	-	-	-	-	-	-
3:15 AM	-		-		-	
3:30 AM	-		-		-	
3:45 AM	-		-		-	
4:00 AM	-	-	-	-	-	-
4:15 AM	-		-		-	
4:30 AM	-		-		-	
4:45 AM	-		-		-	
5:00 AM	-	-	-	-	-	-
5:15 AM	-		-		-	
5:30 AM	-		-		-	
5:45 AM	-		-		-	
6:00 AM	-	237	-	180	-	417
6:15 AM	-		-		-	
6:30 AM	99		69		168	
6:45 AM	138		111		249	
7:00 AM	161	783	144	734	305	1517
7:15 AM	192		185		377	
7:30 AM	224		203		427	
7:45 AM	206		202		408	
8:00 AM	189	567	134	448	323	1015
8:15 AM	145		99		244	
8:30 AM	114		114		228	
8:45 AM	119		101		220	
9:00 AM	109	496	83	373	192	869
9:15 AM	138		89		227	
9:30 AM	136		102		238	
9:45 AM	113		99		212	
10:00 AM	122	526	105	440	227	966
10:15 AM	126		99		225	
10:30 AM	130		116		246	
10:45 AM	148		120		268	
11:00 AM	136	522	120	472	256	994
11:15 AM	148		121		269	
11:30 AM	117		114		231	
11:45 AM	121		117		238	

Begin	EB		WB		Combined	
12:00 PM	128	481	121	514	249	995
12:15 PM	121		142		263	
12:30 PM	118		129		247	
12:45 PM	114		122		236	
1:00 PM	133	528	122	533	255	1061
1:15 PM	129		135		264	
1:30 PM	126		140		266	
1:45 PM	140		136		276	
2:00 PM	143	665	119	617	262	1282
2:15 PM	133		166		299	
2:30 PM	188		154		342	
2:45 PM	201		178		379	
3:00 PM	159	159	169	169	328	328

	EB	WB	Combined
24 Hour Volume	4964 (52.6%)	4480 (47.4%)	9444

12:00 AM - 12:00 PM

	EB	WB	Combined
Count	3131	2647	5778
	54.2 %	45.8 %	
Peak Hour	7:15 AM	7:00 AM	7:15 AM
Volume	811	734	1535
Factor	0.91	0.90	0.90

12:00 PM - 12:00 AM

	EB	WB	Combined
Count	1833	1833	3666
	50.0 %	50.0 %	
Peak Hour	2:15 PM	2:15 PM	2:15 PM
Volume	681	667	1348
Factor	0.85	0.94	0.89

Wilson Okamoto Corporation

1907 S. Beretania Street Suite 400
Honolulu, Hi 96826

Counter:D4-3891, D4-5673
Counted By:DY, JY
Weather:Clear

File Name : PuoKan Midday
Site Code : 00000001
Start Date : 11/23/2010
Page No : 1

Groups Printed- Unshifted

	Puohala Street Southbound				Kaneohe Bay Drive Westbound				Northbound	Kaneohe Bay Drive Eastbound				
Start Time	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	App. Total	Left	Thru	Right	App. Total	Int. Total
11:00 AM	64	0	15	79	0	127	58	185	0	7	110	0	117	381
11:15 AM	42	0	9	51	0	147	57	204	0	5	126	0	131	386
11:30 AM	57	0	11	68	0	116	54	170	0	5	103	0	108	346
11:45 AM	50	0	6	56	0	118	53	171	0	2	99	0	101	328
Total	213	0	41	254	0	508	222	730	0	19	438	0	457	1441
12:00 PM	57	0	5	62	0	121	49	170	0	6	104	0	110	342
12:15 PM	60	0	16	76	0	109	63	172	0	4	121	0	125	373
12:30 PM	53	0	12	65	0	113	51	164	0	5	129	0	134	363
12:45 PM	46	0	10	56	0	121	43	164	0	3	125	0	128	348
Total	216	0	43	259	0	464	206	670	0	18	479	0	497	1426
Grand Total	429	0	84	513	0	972	428	1400	0	37	917	0	954	2867
Apprch %	83.6	0	16.4		0	69.4	30.6			3.9	96.1	0		
Total %	15	0	2.9	17.9	0	33.9	14.9	48.8	0	1.3	32	0	33.3	

	Puohala Street Southbound				Kaneohe Bay Drive Westbound				Northbound	Kaneohe Bay Drive Eastbound				
Start Time	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	App. Total	Left	Thru	Right	App. Total	Int. Total
Peak Hour Analysis From 11:00 AM to 12:45 PM - Peak 1 of 1														
Peak Hour for Entire Intersection Begins at 11:00 AM														
11:00 AM	**64**	0	**15**	**79**	0	127	**58**	185	0	**7**	110	0	117	381
11:15 AM	42	0	9	51	0	**147**	57	**204**	0	5	**126**	0	**131**	**386**
11:30 AM	57	0	11	68	0	116	54	170	0	5	103	0	108	346
11:45 AM	50	0	6	56	0	118	53	171	0	2	99	0	101	328
Total Volume	213	0	41	254	0	508	222	730	0	19	438	0	457	1441
% App. Total	83.9	0	16.1		0	69.6	30.4			4.2	95.8	0		
PHF	.832	.000	.683	.804	.000	.864	.957	.895	.000	.679	.869	.000	.872	.933

Wilson Okamoto Corporation

1907 S. Beretania St., Suite 400
Honolulu, HI 96826

Untitled Vo
Site Code:
Station ID:
Kulauli Street

Latitude: 0' 0.000 Undefined

Start Time	23-Nov-10 Tue	WB Morning	WB Afternoon	Hour Totals Morning	Hour Totals Afternoon	EB Morning	EB Afternoon	Hour Totals Morning	Hour Totals Afternoon	Combined Totals Morning	Combined Totals Afternoon
12:00		*	16			*	16				
12:15		*	8			*	12				
12:30		*	12			*	6				
12:45		*	10	0	46	*	16	0	50	0	96
01:00		*	10			*	8				
01:15		*	4			*	9				
01:30		*	12			*	10				
01:45		*	17	0	43	*	8	0	35	0	78
02:00		*	32			*	31				
02:15		*	26			*	28				
02:30		*	18			*	24				
02:45		*	15	0	91	*	22	0	105	0	196
03:00		*	13			*	16				
03:15		*	5			*	4				
03:30		*	*			*	*				
03:45		*	*	0	18	*	*	0	20	0	38
04:00		*	*			*	*				
04:15		*	*			*	*				
04:30		*	*			*	*				
04:45		*	*	0	0	*	*	0	0	0	0
05:00		*	*			*	*				
05:15		*	*			*	*				
05:30		*	*			*	*				
05:45		*	*	0	0	*	*	0	0	0	0
06:00		*	*			*	*				
06:15		*	*			*	*				
06:30		*	*			*	*				
06:45		*	*	0	0	*	*	0	0	0	0
07:00		*	*			*	*				
07:15		*	*			*	*				
07:30		*	*			*	*				
07:45		*	*	0	0	*	*	0	0	0	0
08:00		*	*			*	*				
08:15		*	*			*	*				
08:30		*	*			*	*				
08:45		9	*	9	0	12	*	12	0	21	0
09:00		10	*			9	*				
09:15		7	*			4	*				
09:30		9	*			16	*				
09:45		5	*	31	0	12	*	41	0	72	0
10:00		12	*			9	*				
10:15		5	*			9	*				
10:30		6	*			11	*				
10:45		9	*	32	0	15	*	44	0	76	0
11:00		6	*			12	*				
11:15		4	*			6	*				
11:30		6	*			5	*				
11:45		10	*	26	0	7	*	30	0	56	0
Total		98	198			127	210			225	408
Percent		33.1%	66.9%			37.7%	62.3%			35.5%	64.5%
Grand Total		98	198			127	210			225	408
Percent		33.1%	66.9%			37.7%	62.3%			35.5%	64.5%

ADT Not Calculated

Wilson Okamoto Corporation

1907 S. Beretania Street Suite 400
Honolulu, Hi 96826

Counter:D4-5676
Counted By:LKC
Weather:Clear

File Name : PuoKul Midday
Site Code : 00000001
Start Date : 11/23/2010
Page No : 1

Groups Printed- Unshifted

	Puohala Street Southbound				Kulauli Street Westbound				Puohala Street Northbound				Kulauli Street Eastbound				
Start Time	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Int. Total
11:00 AM	1	63	0	64	6	2	4	12	1	56	5	62	0	1	1	2	140
11:15 AM	2	47	0	49	2	1	3	6	0	57	2	59	1	0	2	3	117
11:30 AM	2	62	0	64	3	1	1	5	0	57	1	58	0	3	1	4	131
11:45 AM	4	48	1	53	2	2	2	6	0	51	6	57	0	2	0	2	118
Total	9	220	1	230	13	6	10	29	1	221	14	236	1	6	4	11	506
12:00 PM	2	59	3	64	8	3	4	15	0	57	10	67	0	3	0	3	149
12:15 PM	3	52	4	59	7	3	3	13	1	75	3	79	0	1	3	4	155
12:30 PM	3	56	0	59	3	2	0	5	1	40	4	45	0	1	3	4	113
12:45 PM	1	52	0	53	7	2	4	13	1	42	3	46	1	5	2	8	120
Total	9	219	7	235	25	10	11	46	3	214	20	237	1	10	8	19	537
Grand Total	18	439	8	465	38	16	21	75	4	435	34	473	2	16	12	30	1043
Apprch %	3.9	94.4	1.7		50.7	21.3	28		0.8	92	7.2		6.7	53.3	40		
Total %	1.7	42.1	0.8	44.6	3.6	1.5	2	7.2	0.4	41.7	3.3	45.3	0.2	1.5	1.2	2.9	

	Puohala Street Southbound				Kulauli Street Westbound				Puohala Street Northbound				Kulauli Street Eastbound				
Start Time	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Int. Total
Peak Hour Analysis From 11:00 AM to 12:45 PM - Peak 1 of 1																	
Peak Hour for Entire Intersection Begins at 11:30 AM																	
11:30 AM	2	**62**	0	**64**	3	1	1	5	0	57	1	58	0	**3**	1	**4**	131
11:45 AM	**4**	48	1	53	2	2	2	6	0	51	6	57	0	2	0	2	118
12:00 PM	2	59	3	64	**8**	**3**	**4**	**15**	0	57	**10**	67	0	3	0	3	149
12:15 PM	3	52	**4**	59	7	3	3	13	**1**	**75**	3	**79**	0	1	**3**	4	**155**
Total Volume	11	221	8	240	20	9	10	39	1	240	20	261	0	9	4	13	553
% App. Total	4.6	92.1	3.3		51.3	23.1	25.6		0.4	92	7.7		0	69.2	30.8		
PHF	.688	.891	.500	.938	.625	.750	.625	.650	.250	.800	.500	.826	.000	.750	.333	.813	.892

Wilson Okamoto Corporation
1907 S. Beretania St., Suite 400
Honolulu, HI 96826

Description 1: Kaneohe Bay Drive
Description 2: Kailua
Description 3:

Date: 11/23/2010 Tuesday

Daily Volume

Begin	WB		EB		Combined	
12:00 AM	-	-	-	-	-	-
12:15 AM	-		-		-	
12:30 AM	-		-		-	
12:45 AM	-		-		-	
1:00 AM	-	-	-	-	-	-
1:15 AM	-		-		-	
1:30 AM	-		-		-	
1:45 AM	-		-		-	
2:00 AM	-	-	-	-	-	-
2:15 AM	-		-		-	
2:30 AM	-		-		-	
2:45 AM	-		-		-	
3:00 AM	-	-	-	-	-	-
3:15 AM	-		-		-	
3:30 AM	-		-		-	
3:45 AM	-		-		-	
4:00 AM	-	-	-	-	-	-
4:15 AM	-		-		-	
4:30 AM	-		-		-	
4:45 AM	-		-		-	
5:00 AM	-	-	-	-	-	-
5:15 AM	-		-		-	
5:30 AM	-		-		-	
5:45 AM	-		-		-	
6:00 AM	-	-	-	-	-	-
6:15 AM	-		-		-	
6:30 AM	-		-		-	
6:45 AM	-		-		-	
7:00 AM	-	-	-	-	-	-
7:15 AM	-		-		-	
7:30 AM	-		-		-	
7:45 AM	-		-		-	
8:00 AM	22	229	10	108	32	337
8:15 AM	75		27		102	
8:30 AM	76		31		107	
8:45 AM	56		40		96	
9:00 AM	61	234	28	133	89	367
9:15 AM	66		34		100	
9:30 AM	55		34		89	
9:45 AM	52		37		89	
10:00 AM	0	0	36	160	36	160
10:15 AM	0		40		40	
10:30 AM	0		39		39	
10:45 AM	0		45		45	
11:00 AM	0	133	45	168	45	301
11:15 AM	0		45		45	
11:30 AM	59		39		98	
11:45 AM	74		39		113	

Begin	WB		EB		Combined	
12:00 PM	63	287	36	131	99	418
12:15 PM	68		39		107	
12:30 PM	81		32		113	
12:45 PM	75		24		99	
1:00 PM	54	244	30	144	84	388
1:15 PM	53		34		87	
1:30 PM	63		39		102	
1:45 PM	74		41		115	
2:00 PM	58	279	44	190	102	469
2:15 PM	84		41		125	
2:30 PM	71		51		122	
2:45 PM	66		54		120	
3:00 PM	78	374	49	298	127	672
3:15 PM	88		74		162	
3:30 PM	90		92		182	
3:45 PM	118		83		201	
4:00 PM	0	0	1	1	1	1

	WB	EB	Combined
24 Hour Volume	1780 (57.2%)	1333 (42.8%)	3113

12:00 AM - 12:00 PM

	WB	EB	Combined
Count	596	569	1165
	51.2 %	48.8 %	
Peak Hour	8:15 AM	10:30 AM	8:15 AM
Volume	268	174	394
Factor	0.88	0.97	0.92

12:00 PM - 12:00 AM

	WB	EB	Combined
Count	1184	764	1948
	60.8 %	39.2 %	
Peak Hour	3:00 PM	3:00 PM	3:00 PM
Volume	374	298	672
Factor	0.79	0.81	0.84

APPENDIX B

LEVEL OF SERVICE DEFINITIONS

LEVEL OF SERVICE DEFINITIONS

LEVEL-OF-SERVICE CRITERIA FOR SIGNALIZED INTERSECTIONS

Level of Service (LOS) for signalized intersections is defined in terms of delay, which is a measure of driver discomfort, frustration, fuel consumption, and increased travel time. Specifically, level-of-service (LOS) criteria are stated in terms of the average control delay per vehicle, typically a 15-min analysis period. The criteria are given in the following table.

Table 1: Level-of-Service Criteria for Signalized Intersections

Level of Service	Control Delay per Vehicle (sec/veh)
A	≤10.0
B	>10.0 and ≤20.0
C	>20.0 and ≤35.0
D	>35.0 and ≤55.0
E	>55.0 and ≤80.0
F	>80.0

Delay is a complex measure and depends on a number of variables, including the quality of progression, the cycle length, the green ratio, and the v/c ratio for the lane group.

Level of Service A describes operations with low control delay, up to 10 sec per vehicle. This level of service occurs when progression is extremely favorable and most vehicles arrive during the green phase. Many vehicles do not stop at all. Short cycle lengths may tend to contribute to low delay values.

Level of Service B describes operations with control delay greater than 10 and up to 20 sec per vehicle. This level generally occurs with good progression, short cycle lengths, or both. More vehicles stop than with LOS A, causing higher levels of delay.

Level of Service C describes operations with control delay greater than 20 and up to 35 sec per vehicle. These higher delays may result from only fair progression, longer cycle lengths, or both. Individual cycle failures may begin to appear at this level. Cycle failure occurs when a given green phase does not serve queued vehicles and overflows occur. The number of vehicles stopping is significant at this level, though many still pass through the intersection without stopping.

Level of Service D describes operations with control delay greater than 35 and up to 55 sec per vehicle. At level of service D, the influence of congestion becomes more noticeable. Longer delays may result from some combination of unfavorable progression, long cycle lengths, or high v/c ratios. Many vehicles stop, and the proportion of vehicles not stopping declines. Individual cycle failures are noticeable.

"Highway Capacity Manual," Transportation Research Board, 2000.

Level of Service E describes operation with control delay greater than 55 and up to 80 sec per vehicle. These high delay values generally indicate poor progression, long cycle lengths, and high v/c ratios. Individual cycle failures are frequent.

Level of Service F describes operations with control delay in excess of 80 sec per vehicle. This level, considered to be unacceptable to most drivers, often occurs with oversaturation, that is, when arrival flow rates exceed the capacity lane groups. It may also occur at high v/c ratios with many individual cycle failures. Poor progression and long cycle lengths may also contribute significantly to high delay levels.

"Highway Capacity Manual," Transportation Research Board, 2000.

LEVEL OF SERVICE DEFINITIONS

LEVEL-OF-SERVICE CRITERIA FOR UNSIGNALIZED INTERSECTIONS

Level of Service (LOS) criteria are given in Table 1. As used here, control delay is defined as the total elapsed time from the time a vehicle stops at the end of the queue to the time required for the vehicle to travel from the last-in-queue position to the first-in-queue position, including deceleration of vehicles from free-flow speed to the speed of vehicles in the queue.

The average total delay for any particular minor movement is a function of the service rate or capacity of the approach and the degree of saturation. If the degree of saturation is greater than about 0.9, average control delay is significantly affected by the length of the analysis period.

Table 1: Level-of-Service Criteria for Unsignalized Intersections

Level of Service	Average Control Delay (Sec/Veh)
A	≤10.0
B	>10.0 and ≤15.0
C	>15.0 and ≤25.0
D	>25.0 and ≤35.0
E	>35.0 and ≤50.0
F	>50.0

"Highway Capacity Manual," Transportation Research Board, 2000.

LEVEL OF SERVICE DEFINITIONS

LEVEL-OF-SERVICE CRITERIA FOR MULTILANE HIGHWAY

A multilane highway is characterized by three performance measures:

- Density, in terms of passenger cars per mile per lane
- Speed, in terms of mean passenger car speed; and
- Volume to capacity ratio

Each of these measures indicates how well the highway accommodates traffic flow.

Density is the assigned primary performance measure for estimating the level-of-service. The three measures of speed, density, and flow or volume are interrelated. If the values of two of these measures are known, the remaining measure can be computed.

Level of Service A describes completely free-flow conditions. The operation of vehicles is virtually unaffected by the presence of other vehicles, and operations are constrained only by the geometric features of the highway and by driver preferences. Maneuverability within the traffic stream is good. Minor disruptions to flow are easily absorbed without a change in travel speed.

Level of Service B also indicates free flow, although the presence of other vehicles becomes noticeable. Average travel speeds are the same as in LOS A, but drivers have slightly less freedom to maneuver. Minor disruptions are still easily absorbed, although local deterioration in LOS will be more obvious.

In **Level of Service C**, the influence of traffic density on operations become marked. The ability to maneuver within the traffic stream is now clearly affected by other vehicles. On multilane highways with a free-flow speed above 50 mi/h, the travel speeds reduce somewhat. Minor disruptions can cause serious local deterioration in service, and queues will form behind any significant traffic disruption.

At **Level of Service D**, the ability to maneuver is severely restricted due to traffic congestion. Travel speed is reduced by increasing volume. Only minor disruptions can be absorbed without extensive queues forming and the service deteriorating.

Level of Service E represents operations at or near capacity, an unstable level. The densities vary depending on the free-flow speed. Vehicles are operating with the minimum spacing for maintaining uniform flow. Disruptions cannot be dissipated readily, often causing queues to form and service to deteriorate to LOS F. For the majority of multilane highways with free-flow speeds between 45 and 60 mi/h, passenger-car mean speeds at capacity range from 42 to 55 mi/h but are highly variable and unpredictable.

"Highway Capacity Manual," Transportation Research Board, 2000.

Level of Service F represents forced or breakdown flow. It occurs either when vehicles arrive at a rate greater than the rate at which they are discharged or when the forecast demand exceeds the computed capacity of a planned facility. Although operations at these points--and on sections immediately downstream--appear to be at capacity, queues form behind these breakdowns. Operations within queues are highly unstable, with vehicles experiencing brief periods of movement followed by stoppages. Travel speeds within queues are generally less than 30 mi/h. Note that the term LOS F may be used to characterize both the point of the breakdown and the operating condition within the queue.

"Highway Capacity Manual," Transportation Research Board, 2000.

LEVEL OF SERVICE DEFINITIONS

LEVEL-OF-SERVICE CRITERIA FOR A TWO-LANE HIGHWAY

The primary measures of service quality for Class I two-lane highways are percent time-spent-following and average travel speed. For Class II two-lane highways, service quality is based only on percent time-spent-following. LOS criteria are defined for peak 15-min flow periods and are intended for application to segments of significant length.

Level of Service A describes the highest quality of traffic service, when motorists are able to travel at their desired speed. Without strict enforcement, this highest quality would result in average speeds of 55 mi/h or more on two-lane highways in Class I. The passing frequency required to maintain these speeds has not reached a demanding level, so that passing demand is well below passing capacity, and platoons of three or more vehicles are rare. Drivers are delayed no more than 35 percent of their travel time by slow-moving vehicles. A maximum flow rate of 490 pc/h total in both directions may be achieved with base conditions. On Class II highways, speeds may fall below 55 mi/h, but motorists will not be delayed in platoons for more than 40 percent of their travel time.

Level of Service B characterizes traffic flow with speeds of 50 mi/h or slightly higher on level-terrain Class I highways. The demand for passing to maintain desired speeds becomes significant and approximates the passing capacity at the lower boundary of LOS B. Drivers are delayed in platoons up to 50 percent of the time. Service flow rates of 780 pc/h total in both directions can be achieved under base conditions. Above this flow rate, the number of platoons increases dramatically. On Class II highways, speeds may fall below 50 mi/h, but motorists will not be delayed in platoons for more than 55 percent of their travel time.

Level of Service C describes further increases in flow, resulting in noticeable increases in platoon formation, platoon size, and frequency of passing impediments. The average speed still exceeds 45 mi/h on level-terrain Class I highways, even though unrestricted passing demand exceeds passing capacity. At higher volumes the chaining of platoons and significant reductions in passing capacity occur. Although traffic flow is stable, it is susceptible to congestion due to turning traffic and slow-moving vehicles. Percent time-spent-following may reach 65 percent. A service flow rate of up to 1,190 pc/h total in both directions can be accommodated under base conditions. On Class II highways, speeds may fall below 45 mi/h, but motorists will not be delayed in platoons for more than 70 percent of their travel time.

Level of Service D describes unstable traffic flow. The two opposing traffic streams begin to operate separately at higher volume levels, as passing becomes extremely difficult. Passing demand is high, but passing capacity approaches zero. Mean platoon sizes of 5 to 10 vehicles are common, although speeds of 40 mi/h still can be maintained under base conditions on Class I highways. The proportion of no-passing zones along the roadway section usually has little influence on passing. Turning vehicles and roadside distractions cause major shock waves in the traffic stream. Motorists are delayed in

"Highway Capacity Manual," Transportation Research Board, 2000.

platoons for nearly 80 percent of their travel time. Maximum service flow rates of 1,830 pc/h total in both directions can be maintained under base conditions. On Class II highways, speeds may fall below 40 mi/h, but in no case will motorists be delayed in platoons for more than 85 percent of their travel time.

At **Level of Service E**, traffic flow conditions have a percent time-spent-following greater than 80 percent on Class I highways and greater than 85 percent on Class II. Even under base conditions, speeds may drop below 40 mi/h. Average travel speeds on highways with less than base conditions will be slower, even down to 25 mi/h on sustained upgrades. Passing is virtually impossible at LOS E, and platooning becomes intense, as slower vehicles or other interruptions are encountered.

The highest volume attainable under LOS E defines the capacity of the highway, generally 3,200 pc/h total in both directions. Operating conditions at capacity are unstable and difficult to predict. Traffic operations seldom reach near capacity on rural highways, primarily because of lack of demand.

Level of Service F represents heavily congested flow with traffic demand exceeding capacity. Volumes are lower than capacity and speeds are highly variable.

"Highway Capacity Manual," Transportation Research Board, 2000.

APPENDIX C

CAPACITY ANALYSIS CALCULATIONS
BASELINE PEAK HOUR TRAFFIC ANALYSIS

HCS+: Unsignalized Intersections Release 5.4

TWO-WAY STOP CONTROL SUMMARY

Analyst: CL
Agency/Co.:
Date Performed: 11/30/2010
Analysis Time Period: Mid-day Peak
Intersection:
Jurisdiction:
Units: U. S. Customary
Analysis Year: Existing
Project ID:
East/West Street: Kulauli
North/South Street: Puohala
Intersection Orientation: NS   Study period (hrs): 0.25

Vehicle Volumes and Adjustments

Major Street: Approach	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume	2	217	22	12	223	8
Peak-Hour Factor, PHF	0.78	0.78	0.78	0.92	0.92	0.92
Hourly Flow Rate, HFR	2	278	28	13	242	8
Percent Heavy Vehicles	2	--	--	2	--	--
Median Type/Storage	Undivided			/		
RT Channelized?						
Lanes	0	1	0	0	1	0
Configuration	LTR			LTR		
Upstream Signal?		No			No	

Minor Street: Approach	Westbound			Eastbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume	20	10	9	0	7	6
Peak Hour Factor, PHF	0.65	0.65	0.65	0.81	0.81	0.81
Hourly Flow Rate, HFR	30	15	13	0	8	7
Percent Heavy Vehicles	2	2	2	2	2	2
Percent Grade (%)		0			0	
Flared Approach: Exists?/Storage			No /			No /
Lanes	0	1	0	0	1	0
Configuration		LTR			LTR	

Delay, Queue Length, and Level of Service

Approach	NB	SB	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Config	LTR	LTR		LTR			LTR	
v (vph)	2	13		58			15	
C(m) (vph)	1316	1255		463			537	
v/c	0.00	0.01		0.13			0.03	
95% queue length	0.00	0.03		0.43			0.09	
Control Delay	7.7	7.9		13.9			11.9	
LOS	A	A		B			B	
Approach Delay				13.9			11.9	
Approach LOS				B			B	

HCS+: Signalized Intersections Release 5.4

Analyst: CL
Agency:
Date: 11/30/2010
Period: Mid-day Peak
Project ID:
E/W St: Kaneohe Bay Dr

Inter.:
Area Type: All other areas
Jurisd:
Year : Existing

N/S St:

SIGNALIZED INTERSECTION SUMMARY

	Eastbound L	Eastbound T	Eastbound R	Westbound L	Westbound T	Westbound R	Northbound L	Northbound T	Northbound R	Southbound L	Southbound T	Southbound R
No. Lanes	1	2	0	0	2	0	0	0	0	0	0	0
LGConfig	L	T			TR						LR	
Volume	18	453			461	223				219		30
Lane Width	12.0	12.0			12.0						12.0	
RTOR Vol						22						3

Duration 0.25 Area Type: All other areas

Signal Operations

Phase Combination	1	2	3	4			5	6	7	8
EB Left	A				NB	Left				
Thru	A					Thru				
Right						Right				
Peds						Peds				
WB Left					SB	Left	A			
Thru	A					Thru				
Right	A					Right	A			
Peds						Peds				
NB Right					EB	Right				
SB Right					WB	Right				
Green	50.0						30.0			
Yellow	4.0						4.0			
All Red	1.0						1.0			

Cycle Length: 90.0 secs

Intersection Performance Summary

Appr/ Lane Grp	Lane Group Capacity	Adj Sat Flow Rate (s)	Ratios v/c	Ratios g/C	Lane Group Delay	Lane Group LOS	Approach Delay	Approach LOS
Eastbound								
L	370	666	0.05	0.56	9.2	A		
T	1971	3547	0.26	0.56	10.5	B	10.4	B
Westbound								
TR	1881	3385	0.36	0.56	11.2	B	11.2	B
Northbound								
Southbound								
LR	586	1757	0.49	0.33	24.6	C	24.6	C

Intersection Delay = 13.5 (sec/veh) Intersection LOS = B

HCS+: Multilane Highways Release 5.4

Phone: Fax:
E-mail:

OPERATIONAL ANALYSIS

Analyst: CL
Agency/Co:
Date: 11/30/2010
Analysis Period: Mid-day peak
Highway: Kaneohe Bay
From/To: Kaneohe
Jurisdiction:
Analysis Year: Existing
Project ID:

FREE-FLOW SPEED

Direction	1		2	
Lane width	12.0	ft	12.0	ft
Lateral clearance:				
Right edge	6.0	ft	6.0	ft
Left edge	6.0	ft	6.0	ft
Total lateral clearance	12.0	ft	12.0	ft
Access points per mile	20		20	
Median type	Divided		Divided	
Free-flow speed:	Base		Base	
FFS or BFFS	50.0	mph	50.0	mph
Lane width adjustment, FLW	0.0	mph	0.0	mph
Lateral clearance adjustment, FLC	0.0	mph	0.0	mph
Median type adjustment, FM	0.0	mph	0.0	mph
Access points adjustment, FA	5.0	mph	5.0	mph
Free-flow speed	45.0	mph	45.0	mph

VOLUME

Direction	1		2	
Volume, V	488	vph	509	vph
Peak-hour factor, PHF	0.85		0.95	
Peak 15-minute volume, v15	144		134	
Trucks and buses	2	%	2	%
Recreational vehicles	0	%	0	%
Terrain type	Level		Level	
Grade	0.00	%	0.00	%
Segment length	0.00	mi	0.00	mi
Number of lanes	2		2	
Driver population adjustment, fP	1.00		1.00	
Trucks and buses PCE, ET	1.5		1.5	
Recreational vehicles PCE, ER	1.2		1.2	

Heavy vehicle adjustment, fHV	0.990		0.990	
Flow rate, vp	289	pcphpl	270	pcphpl

RESULTS

Direction	1		2	
Flow rate, vp	289	pcphpl	270	pcphpl
Free-flow speed, FFS	45.0	mph	45.0	mph
Avg. passenger-car travel speed, S	45.0	mph	45.0	mph
Level of service, LOS	A		A	
Density, D	6.4	pc/mi/ln	6.0	pc/mi/ln

Overall results are not computed when free-flow speed is less than 45 mph.

HCS+: Two-Lane Highways Release 5.4

Phone: Fax:
E-Mail:

Two-Way Two-Lane Highway Segment Analysis

Analyst	CL
Agency/Co.	
Date Performed	11/30/2010
Analysis Time Period	Mid-day Peak
Highway	Kaneohe Bay Dr
From/To	Kailua
Jurisdiction	
Analysis Year	Existing
Description	

Input Data

Highway class Class 1

Shoulder width	6.0	ft	Peak-hour factor, PHF	0.96	
Lane width	12.0	ft	% Trucks and buses	2	%
Segment length	0.0	mi	% Recreational vehicles	0	%
Terrain type	Level		% No-passing zones	0	%
Grade: Length		mi	Access points/mi	20	/mi
Up/down		%			

Two-way hourly volume, V 417 veh/h
Directional split 63 / 37 %

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.986	
Two-way flow rate,(note-1) vp	440	pc/h
Highest directional split proportion (note-2)	277	pc/h
Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	60.0	mi/h
Adj. for lane and shoulder width, fLS	0.0	mi/h
Adj. for access points, fA	5.0	mi/h
Free-flow speed, FFS	55.0	mi/h
Adjustment for no-passing zones, fnp	0.0	mi/h
Average travel speed, ATS	51.6	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.998	
Two-way flow rate,(note-1) vp	435	pc/h
Highest directional split proportion (note-2)	274	
Base percent time-spent-following, BPTSF	31.8	%
Adj.for directional distribution and no-passing zones, fd/np	0.4	
Percent time-spent-following, PTSF	32.2	%

Level of Service and Other Performance Measures

Level of service, LOS	B	
Volume to capacity ratio, v/c	0.14	
Peak 15-min vehicle-miles of travel, VMT15	0	veh-mi
Peak-hour vehicle-miles of travel, VMT60	0	veh-mi
Peak 15-min total travel time, TT15	0.0	veh-h

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.

APPENDIX D

CONSTRUCTION-RELATED TRUCK TRAFFIC PROJECTIONS

APPENDIX E

CAPACITY ANALYSIS CALCULATIONS
PROJECTED PEAK HOUR TRAFFIC
ANALYSIS WITH CONSTRUCTION TRAFFIC
(AVERAGE)

Kailua-Kaneohe Conveyance Tunnel - Truck Traffic Estimates[1] Revised 11/29/2010

Location	Activity	Time Frame (months)[3]	Daily Truck Traffic (Roundtrips[2]) Min	Max	Avg
Kailua[4]	Mobilization/Shaft Development	0 to 13	5	35	12
	Tunnel Excavation	13 to 25	10	100	55
	Tunnel Lining Operations	26 to 31	5	30	23
	Clean up and Demob	31 to 32	5	10	7
Kaneohe	Mobilization/Shaft Development	0 to 6	5	30	15
	Tunnel Excavation	5 to 11	10	40	25
	Drop Structure Construction	29 to 30.5	5	25	13
	Clean up and Demob	30.5 to 31	5	10	7
Access Shaft (BWS Site)	Shaft Excavation	25 to 26	5	10	8
	Shaft Lining and Structure Cons.	26 to 27	5	20	10
	Clean up and Demob	27 to 28	3	10	5

[1] Time frames and traffic estimates are approximate .

[2] Each roundtrip includes the truck entering and leaving the site.

[3] Assume minimal truck traffic (1 to 2/day) where there are gaps between activities.

[4] Does not include IPS construction.

APPENDIX F

CAPACITY ANALYSIS CALCULATIONS
PROJECTED PEAK HOUR TRAFFIC
ANALYSIS WITH CONSTRUCTION TRAFFIC
(MAXIMUM)

HCS+: Unsignalized Intersections Release 5.4

TWO-WAY STOP CONTROL SUMMARY

Analyst: CL
Agency/Co.:
Date Performed: 11/30/2010
Analysis Time Period: Mid-day Peak
Intersection:
Jurisdiction:
Units: U. S. Customary
Analysis Year: w/ construction traffic - ave
Project ID:
East/West Street: Kulauli
North/South Street: Puohala
Intersection Orientation: NS Study period (hrs): 0.25

Vehicle Volumes and Adjustments

Major Street:	Approach	Northbound			Southbound		
	Movement	1	2	3	4	5	6
		L	T	R	L	T	R
Volume		2	217	27	12	223	8
Peak-Hour Factor, PHF		0.78	0.78	0.78	0.92	0.92	0.92
Hourly Flow Rate, HFR		2	278	34	13	242	8
Percent Heavy Vehicles		2	--	--	2	--	--
Median Type/Storage		Undivided			/		
RT Channelized?							
Lanes		0	1	0	0	1	0
Configuration			LTR			LTR	
Upstream Signal?			No			No	

Minor Street:	Approach	Westbound			Eastbound		
	Movement	7	8	9	10	11	12
		L	T	R	L	T	R
Volume		25	10	9	0	7	6
Peak Hour Factor, PHF		0.65	0.65	0.65	0.81	0.81	0.81
Hourly Flow Rate, HFR		38	15	13	0	8	7
Percent Heavy Vehicles		20	2	2	2	2	2
Percent Grade (%)			0			0	
Flared Approach:	Exists?/Storage			No	/		No /
Lanes		0	1	0	0	1	0
Configuration			LTR			LTR	

Delay, Queue Length, and Level of Service

Approach	NB	SB	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Config	LTR	LTR		LTR			LTR	
v (vph)	2	13		66			15	
C(m) (vph)	1316	1248		437			534	
v/c	0.00	0.01		0.15			0.03	
95% queue length	0.00	0.03		0.53			0.09	
Control Delay	7.7	7.9		14.7			11.9	
LOS	A	A		B			B	
Approach Delay				14.7			11.9	
Approach LOS				B			B	

HCS+: Signalized Intersections Release 5.4

Analyst: CL
Agency:
Date: 11/30/2010
Period: Mid-day Peak
Project ID:
E/W St: Kaneohe Bay Dr

Inter.:
Area Type: All other areas
Jurisd:
Year : w/ construction - ave
N/S St:

SIGNALIZED INTERSECTION SUMMARY

	Eastbound L	Eastbound T	Eastbound R	Westbound L	Westbound T	Westbound R	Northbound L	Northbound T	Northbound R	Southbound L	Southbound T	Southbound R
No. Lanes	1	2	0	0	2	0	0	0	0	0	0	0
LGConfig	L	T			TR						LR	
Volume	23	453			461	223				219		35
Lane Width	12.0	12.0			12.0						12.0	
RTOR Vol						22						4

Duration 0.25 Area Type: All other areas

Signal Operations

Phase Combination	1	2	3	4			5	6	7	8
EB Left	A				NB	Left				
Thru	A					Thru				
Right						Right				
Peds						Peds				
WB Left					SB	Left	A			
Thru	A					Thru				
Right	A					Right	A			
Peds						Peds				
NB Right					EB	Right				
SB Right					WB	Right				
Green	50.0						30.0			
Yellow	4.0						4.0			
All Red	1.0						1.0			

Cycle Length: 90.0 secs

Intersection Performance Summary

Appr/ Lane Grp	Lane Group Capacity	Adj Sat Flow Rate (s)	Ratios v/c	Ratios g/C	Lane Group Delay	Lane Group LOS	Approach Delay	Approach LOS
Eastbound								
L	314	566	0.08	0.56	9.4	A		
T	1971	3547	0.26	0.56	10.5	B	10.4	B
Westbound								
TR	1881	3385	0.36	0.56	11.2	B	11.2	B
Northbound								
Southbound								
LR	576	1728	0.51	0.33	24.9	C	24.9	C

Intersection Delay = 13.6 (sec/veh) Intersection LOS = B

HCS+: Multilane Highways Release 5.4

Phone: Fax:
E-mail:

OPERATIONAL ANALYSIS

Analyst: CL
Agency/Co:
Date: 11/30/2010
Analysis Period: Mid-day peak
Highway: Kaneohe Bay
From/To: Kaneohe
Jurisdiction:
Analysis Year: w/ construction - ave
Project ID:

FREE-FLOW SPEED

Direction	1		2	
Lane width	12.0	ft	12.0	ft
Lateral clearance:				
Right edge	6.0	ft	6.0	ft
Left edge	6.0	ft	6.0	ft
Total lateral clearance	12.0	ft	12.0	ft
Access points per mile	20		20	
Median type	Divided		Divided	
Free-flow speed:	Base		Base	
FFS or BFFS	50.0	mph	50.0	mph
Lane width adjustment, FLW	0.0	mph	0.0	mph
Lateral clearance adjustment, FLC	0.0	mph	0.0	mph
Median type adjustment, FM	0.0	mph	0.0	mph
Access points adjustment, FA	5.0	mph	5.0	mph
Free-flow speed	45.0	mph	45.0	mph

VOLUME

Direction	1		2	
Volume, V	493	vph	514	vph
Peak-hour factor, PHF	0.85		0.95	
Peak 15-minute volume, v15	145		135	
Trucks and buses	2	%	2	%
Recreational vehicles	0	%	0	%
Terrain type	Level		Level	
Grade	0.00	%	0.00	%
Segment length	0.00	mi	0.00	mi
Number of lanes	2		2	
Driver population adjustment, fP	1.00		1.00	
Trucks and buses PCE, ET	1.5		1.5	
Recreational vehicles PCE, ER	1.2		1.2	

Heavy vehicle adjustment, fHV	0.990		0.990	
Flow rate, vp	292	pcphpl	273	pcphpl

RESULTS

Direction	1		2	
Flow rate, vp	292	pcphpl	273	pcphpl
Free-flow speed, FFS	45.0	mph	45.0	mph
Avg. passenger-car travel speed, S	45.0	mph	45.0	mph
Level of service, LOS	A		A	
Density, D	6.5	pc/mi/ln	6.1	pc/mi/ln

Overall results are not computed when free-flow speed is less than 45 mph.

HCS+: Two-Lane Highways Release 5.4

Phone: Fax:
E-Mail:

Two-Way Two-Lane Highway Segment Analysis

Analyst	CL
Agency/Co.	
Date Performed	11/30/2010
Analysis Time Period	Mid-day Peak
Highway	Kaneohe Bay Dr
From/To	Kailua
Jurisdiction	
Analysis Year	w/ construction - ave
Description	

Input Data

Highway class Class 1

Shoulder width	6.0	ft	Peak-hour factor, PHF	0.96	
Lane width	12.0	ft	% Trucks and buses	5	%
Segment length	0.0	mi	% Recreational vehicles	0	%
Terrain type	Level		% No-passing zones	0	%
Grade: Length		mi	Access points/mi	20	/mi
Up/down		%			

Two-way hourly volume, V 437 veh/h
Directional split 63 / 37 %

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.966	
Two-way flow rate,(note-1) vp	471	pc/h
Highest directional split proportion (note-2)	297	pc/h
Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	60.0	mi/h
Adj. for lane and shoulder width, fLS	0.0	mi/h
Adj. for access points, fA	5.0	mi/h
Free-flow speed, FFS	55.0	mi/h
Adjustment for no-passing zones, fnp	0.0	mi/h
Average travel speed, ATS	51.3	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.995	
Two-way flow rate,(note-1) vp	457	pc/h
Highest directional split proportion (note-2)	288	
Base percent time-spent-following, BPTSF	33.1	%
Adj.for directional distribution and no-passing zones, fd/np	0.4	
Percent time-spent-following, PTSF	33.4	%

Level of Service and Other Performance Measures

Level of service, LOS	B	
Volume to capacity ratio, v/c	0.15	
Peak 15-min vehicle-miles of travel, VMT15	0	veh-mi
Peak-hour vehicle-miles of travel, VMT60	0	veh-mi
Peak 15-min total travel time, TT15	0.0	veh-h

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.

APPENDIX F

CAPACITY ANALYSIS CALCULATIONS
PROJECTED PEAK HOUR TRAFFIC
ANALYSIS WITH CONSTRUCTION TRAFFIC
(MAXIMUM)

HCS+: Unsignalized Intersections Release 5.4

TWO-WAY STOP CONTROL SUMMARY

Analyst: CL
Agency/Co.:
Date Performed: 11/30/2010
Analysis Time Period: Mid-day Peak
Intersection:
Jurisdiction:
Units: U. S. Customary
Analysis Year: w/ construction traffic - max
Project ID:
East/West Street: Kulauli
North/South Street: Puohala
Intersection Orientation: NS Study period (hrs): 0.25

Vehicle Volumes and Adjustments

Major Street: Approach	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume	2	217	29	12	223	8
Peak-Hour Factor, PHF	0.78	0.78	0.78	0.92	0.92	0.92
Hourly Flow Rate, HFR	2	278	37	13	242	8
Percent Heavy Vehicles	2	--	--	2	--	--
Median Type/Storage	Undivided			/		
RT Channelized?						
Lanes	0	1	0	0	1	0
Configuration		LTR			LTR	
Upstream Signal?		No			No	

Minor Street: Approach	Westbound			Eastbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume	27	10	9	0	7	6
Peak Hour Factor, PHF	0.65	0.65	0.65	0.81	0.81	0.81
Hourly Flow Rate, HFR	41	15	13	0	8	7
Percent Heavy Vehicles	25	2	2	2	2	2
Percent Grade (%)		0			0	
Flared Approach: Exists?/Storage			No /			No /
Lanes	0	1	0	0	1	0
Configuration		LTR			LTR	

Delay, Queue Length, and Level of Service

Approach	NB	SB	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Config	LTR	LTR		LTR			LTR	
v (vph)	2	13		69			15	
C(m) (vph)	1316	1245		429			533	
v/c	0.00	0.01		0.16			0.03	
95% queue length	0.00	0.03		0.57			0.09	
Control Delay	7.7	7.9		15.0			11.9	
LOS	A	A		B			B	
Approach Delay				15.0			11.9	
Approach LOS				B			B	

HCS+: Signalized Intersections Release 5.4

Analyst: CL	Inter.:
Agency:	Area Type: All other areas
Date: 11/30/2010	Jurisd:
Period: Mid-day Peak	Year : w/ construction - max
Project ID:	
E/W St: Kaneohe Bay Dr	N/S St:

SIGNALIZED INTERSECTION SUMMARY

	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	1	2	0	0	2	0	0	0	0	0	0	0
LGConfig	L	T			TR						LR	
Volume	25	453			461	223				219		37
Lane Width	12.0	12.0			12.0						12.0	
RTOR Vol						22						4

Duration 0.25 Area Type: All other areas

Signal Operations

Phase Combination	1	2	3	4		5	6	7	8
EB Left	A				NB Left				
Thru	A				Thru				
Right					Right				
Peds					Peds				
WB Left					SB Left	A			
Thru	A				Thru				
Right	A				Right	A			
Peds					Peds				
NB Right					EB Right				
SB Right					WB Right				
Green	50.0					30.0			
Yellow	4.0					4.0			
All Red	1.0					1.0			

Cycle Length: 90.0 secs

Intersection Performance Summary

Appr/ Lane Grp	Lane Group Capacity	Adj Sat Flow Rate (s)	Ratios v/c	Ratios g/C	Lane Group Delay	Lane Group LOS	Approach Delay	Approach LOS
Eastbound								
L	302	543	0.09	0.56	9.5	A		
T	1971	3547	0.26	0.56	10.5	B	10.4	B
Westbound								
TR	1881	3385	0.36	0.56	11.2	B	11.2	B
Northbound								
Southbound								
LR	571	1714	0.52	0.33	25.1	C	25.1	C

Intersection Delay = 13.6 (sec/veh) Intersection LOS = B

HCS+: Multilane Highways Release 5.4

Phone: Fax:
E-mail:

OPERATIONAL ANALYSIS

Analyst: CL
Agency/Co:
Date: 11/30/2010
Analysis Period: Mid-day peak
Highway: Kaneohe Bay
From/To: Kaneohe
Jurisdiction:
Analysis Year: w/ construction - max
Project ID:

FREE-FLOW SPEED

Direction	1		2	
Lane width	12.0	ft	12.0	ft
Lateral clearance:				
Right edge	6.0	ft	6.0	ft
Left edge	6.0	ft	6.0	ft
Total lateral clearance	12.0	ft	12.0	ft
Access points per mile	20		20	
Median type	Divided		Divided	
Free-flow speed:	Base		Base	
FFS or BFFS	50.0	mph	50.0	mph
Lane width adjustment, FLW	0.0	mph	0.0	mph
Lateral clearance adjustment, FLC	0.0	mph	0.0	mph
Median type adjustment, FM	0.0	mph	0.0	mph
Access points adjustment, FA	5.0	mph	5.0	mph
Free-flow speed	45.0	mph	45.0	mph

VOLUME

Direction	1		2	
Volume, V	495	vph	516	vph
Peak-hour factor, PHF	0.85		0.95	
Peak 15-minute volume, v15	146		136	
Trucks and buses	2	%	2	%
Recreational vehicles	0	%	0	%
Terrain type	Level		Level	
Grade	0.00	%	0.00	%
Segment length	0.00	mi	0.00	mi
Number of lanes	2		2	
Driver population adjustment, fP	1.00		1.00	
Trucks and buses PCE, ET	1.5		1.5	
Recreational vehicles PCE, ER	1.2		1.2	

Heavy vehicle adjustment, fHV	0.990		0.990	
Flow rate, vp	294	pcphpl	274	pcphpl

RESULTS

Direction	1		2	
Flow rate, vp	294	pcphpl	274	pcphpl
Free-flow speed, FFS	45.0	mph	45.0	mph
Avg. passenger-car travel speed, S	45.0	mph	45.0	mph
Level of service, LOS	A		A	
Density, D	6.5	pc/mi/ln	6.1	pc/mi/ln

Overall results are not computed when free-flow speed is less than 45 mph.

HCS+: Two-Lane Highways Release 5.4

Phone: Fax:
E-Mail:

Two-Way Two-Lane Highway Segment Analysis

Analyst	CL
Agency/Co.	
Date Performed	11/30/2010
Analysis Time Period	Mid-day Peak
Highway	Kaneohe Bay Dr
From/To	Kailua
Jurisdiction	
Analysis Year	w/ construction - max
Description	

Input Data

Highway class Class 1

Shoulder width	6.0	ft	Peak-hour factor, PHF	0.96	
Lane width	12.0	ft	% Trucks and buses	8	%
Segment length	0.0	mi	% Recreational vehicles	0	%
Terrain type	Level		% No-passing zones	0	%
Grade: Length		mi	Access points/mi	20	/mi
Up/down		%			

Two-way hourly volume, V 451 veh/h
Directional split 62 / 38 %

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.947	
Two-way flow rate,(note-1) vp	496	pc/h
Highest directional split proportion (note-2)	308	pc/h
Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	60.0	mi/h
Adj. for lane and shoulder width, fLS	0.0	mi/h
Adj. for access points, fA	5.0	mi/h
Free-flow speed, FFS	55.0	mi/h
Adjustment for no-passing zones, fnp	0.0	mi/h
Average travel speed, ATS	51.2	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.992	
Two-way flow rate,(note-1) vp	474	pc/h
Highest directional split proportion (note-2)	294	
Base percent time-spent-following, BPTSF	34.1	%
Adj.for directional distribution and no-passing zones, fd/np	0.3	
Percent time-spent-following, PTSF	34.4	%

Level of Service and Other Performance Measures

Level of service, LOS	B	
Volume to capacity ratio, v/c	0.16	
Peak 15-min vehicle-miles of travel, VMT15	0	veh-mi
Peak-hour vehicle-miles of travel, VMT60	0	veh-mi
Peak 15-min total travel time, TT15	0.0	veh-h

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.

Appendix O

Traffic Assessment - Kaneohe / Kailua Force Main No. 2 Addendum
Austin Tsutsumi & Associates, Inc.
January 2011

Traffic Assessment Kaneohe / Kailua Force Main No. 2
Austin Tsutsumi & Associates, Inc.
December 2010

AUSTIN, TSUTSUMI & ASSOCIATES, INC. CIVIL ENGINEERS • SURVEYORS
CONTINUING THE ENGINEERING PRACTICE FOUNDED BY H. A. R. AUSTIN IN 1934

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TERRANCE S. ARASHIRO, P.E.
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STANLEY T. WATANABE
IVAN K. NAKATSUKA, P.E.
ADRIENNE W. L. H. WONG, P.E., LEED AP

06-080.3
January 4, 2011

Mrs. Jann Dacanay
City and County of Honolulu
Department of Design and Construction
Wastewater Division, Wastewater Design Branch
650 S. King Street, 14th Floor
Honolulu, Hawaii 96813

Dear Mrs. Dacanay:

Subject: Traffic Assessment – Kaneohe/Kailua Force Main No. 2 Addendum

This Addendum is intended to update the Traffic Assessment for the Kaneohe/Kailua Force Main No. 2, dated December 8, 2010 (TA) in the following ways:

1. Level-of-Service (LOS) analysis for Mid-Day conditions included for:
   a. Kaneohe Wastewater Pre-Treatment Facility (South Site)
   b. Kailua Regional Wastewater Treatment Plant (North Site)
2. Updated discussion regarding Traffic Control Plans (TCP)
3. Recommendation of future Construction Management Plan (CMP)

Level-Of-Service Analysis

Mid-day Peak Hour conditions were analyzed to represent the heaviest traffic while construction-related truck traffic is expected to occur[1].

South Site

Figures 1 and 2 depict the Baseline and with-Project condition, which will add as many as 6 heavy vehicles per hour traveling between the South Site and either the North Site or the Waianae Landfill.

As can be seen in Table 1, the Kaneohe Bay Drive/Puohala Street and Puohala Street/Kulauli Street both currently operate at LOS C or better on all approaches with and without the construction-related traffic.

[1] As per the recommendations of the TA, construction hours will be between 8:30 AM and 3:00 PM; truck traffic will be further restricted to avoid school dismissal period (varies).

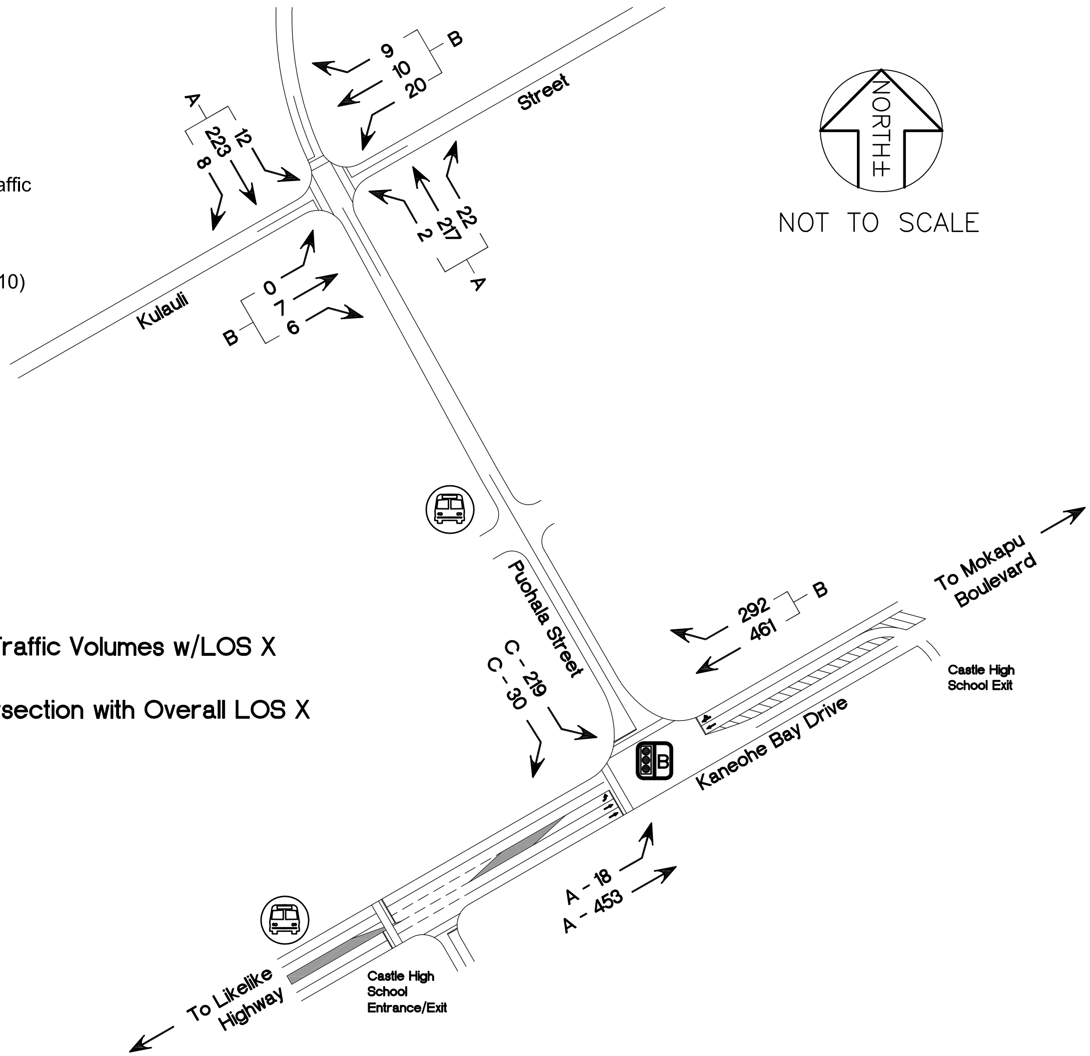
REPLY TO:
501 SUMNER STREET, SUITE 521 • HONOLULU, HAWAII 96817-5031
PHONE (808) 533-3646 • FAX (808) 526-1267
EMAIL : atahnl@atahawaii.com

OFFICES IN:
HONOLULU, HAWAII
WAILUKU, MAUI, HAWAII
HILO, HAWAII

DATE OF COUNTS:
November 23rd, 2010*

MIDDAY PEAK HOUR:
11:45 AM - 12:45 PM

*Data obtained from Construction Traffic Impact Report for Kaneohe to Kailua Conveyance & Treatment Facility, Gravity Tunnel Alternative (Wilson Okamoto Corporation, December 2010)



LEGEND:

- TheBus Stop

X - ## = Midday Peak Hour of Traffic Volumes w/LOS X

X - Signalized Intersection with Overall LOS X

KANEOHE/KAILUA FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

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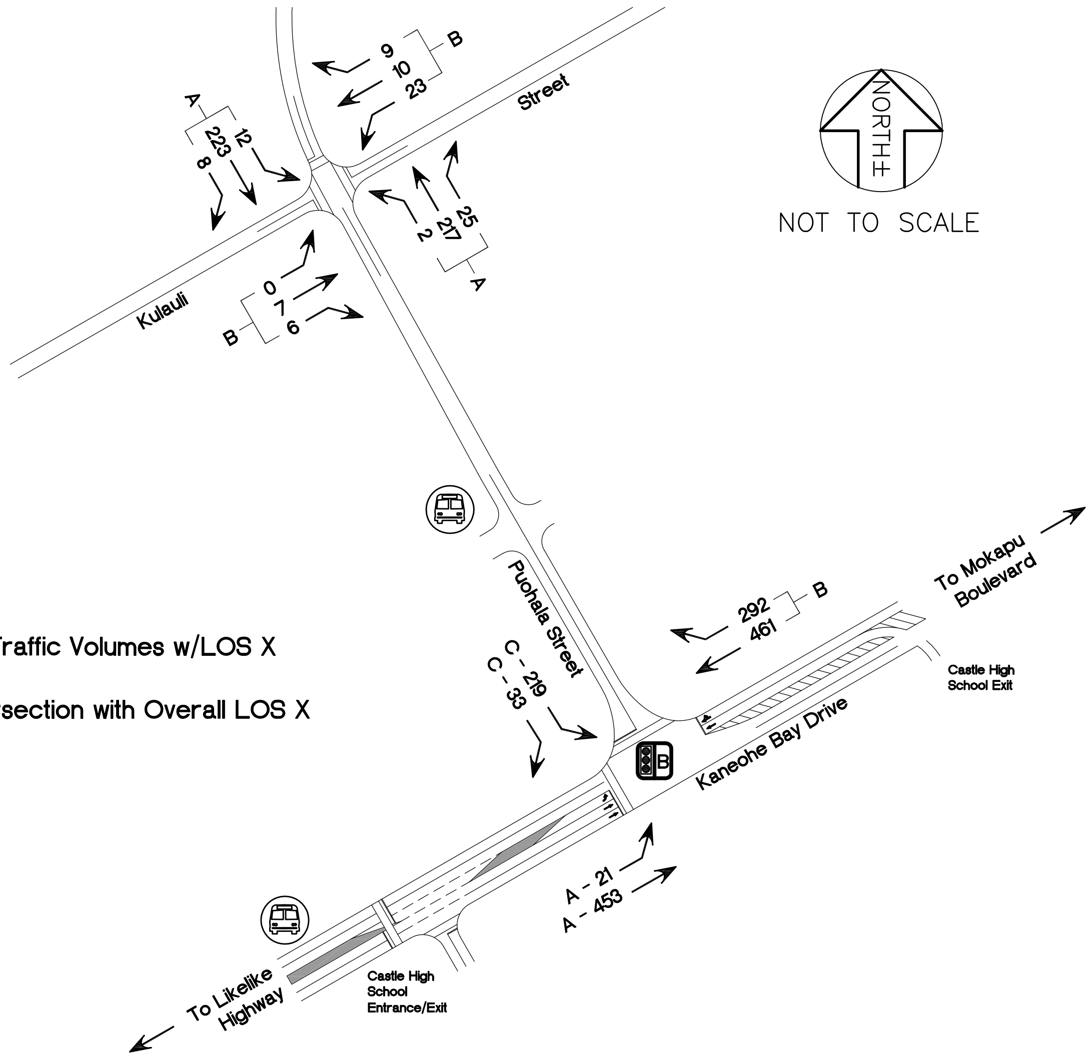
SOUTH SITE EXISTING CONDITIONS

FIGURE 1



LEGEND:

- TheBus Stop

X - ## = Midday Peak Hour of Traffic Volumes w/LOS X

X - Signalized Intersection with Overall LOS X

KANEOHE/KAILUA FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

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SOUTH SITE WITH PROJECT

FIGURE 2

TABLE 1: South Site
Level of Service Summary

Intersection	Existing Conditions (Midday) HCM Delay	v/c Ratio	LOS	With Project (Midday) HCM Delay	v/c Ratio	LOS
Kaneohe Bay Drive/Puohala Street						
EB LT	7.4	0.18	A	7.7	0.21	A
EB TH	6.6	0.23	A	6.6	0.23	A
WB TH/RT	14.2	0.77	B	14.2	0.77	B
SB LT	25.7	0.58	C	25.7	0.58	C
SB RT	20.4	0.05	C	20.4	0.05	C
Overall	13.6	0.72	B	13.6	0.72	B
Puohala Street/Kulauli Street						
EB LT/TH/RT	11.6	0.03	B	11.6	0.03	B
WB LT/TH/RT	13.0	0.09	B	13.1	0.09	B
NT LT/TH/RT	0.1	0.00	A	0.1	0.00	A
SB LT/TH/RT	0.5	0.01	A	0.5	0.01	A

North Site

Figures 3 and 4 depict the Baseline and with-Project conditions; as with the South Site analysis, 6 heavy vehicles per hour are projected to travel between the North Site and either the South Site or the Waianae Landfill.

As can be seen in Table 2 below, operations along Kaneohe Bay Drive will not be substantively affected by the Project-related heavy vehicle traffic. The TCP allows for left-turn in/out access to be maintained for at least two (2) of the four (4) accesses to the Aikahi Gardens townhouses during any given phase. These include: Molo Street, Lale Street, Kuau Street, and Halia Street, as left-turn in and out access will be restricted on two of them at a time.

As such, the left-turn existing entering and exiting volume has been doubled at Molo Street and Lale Street to represent the closure of Kuau Street and Halia Street.

All of the studied intersections should continue to operate at LOS B or better during the Mid-Day Peak Hour with and without the Project.

DATE OF COUNTS:
November 23rd, 2010*

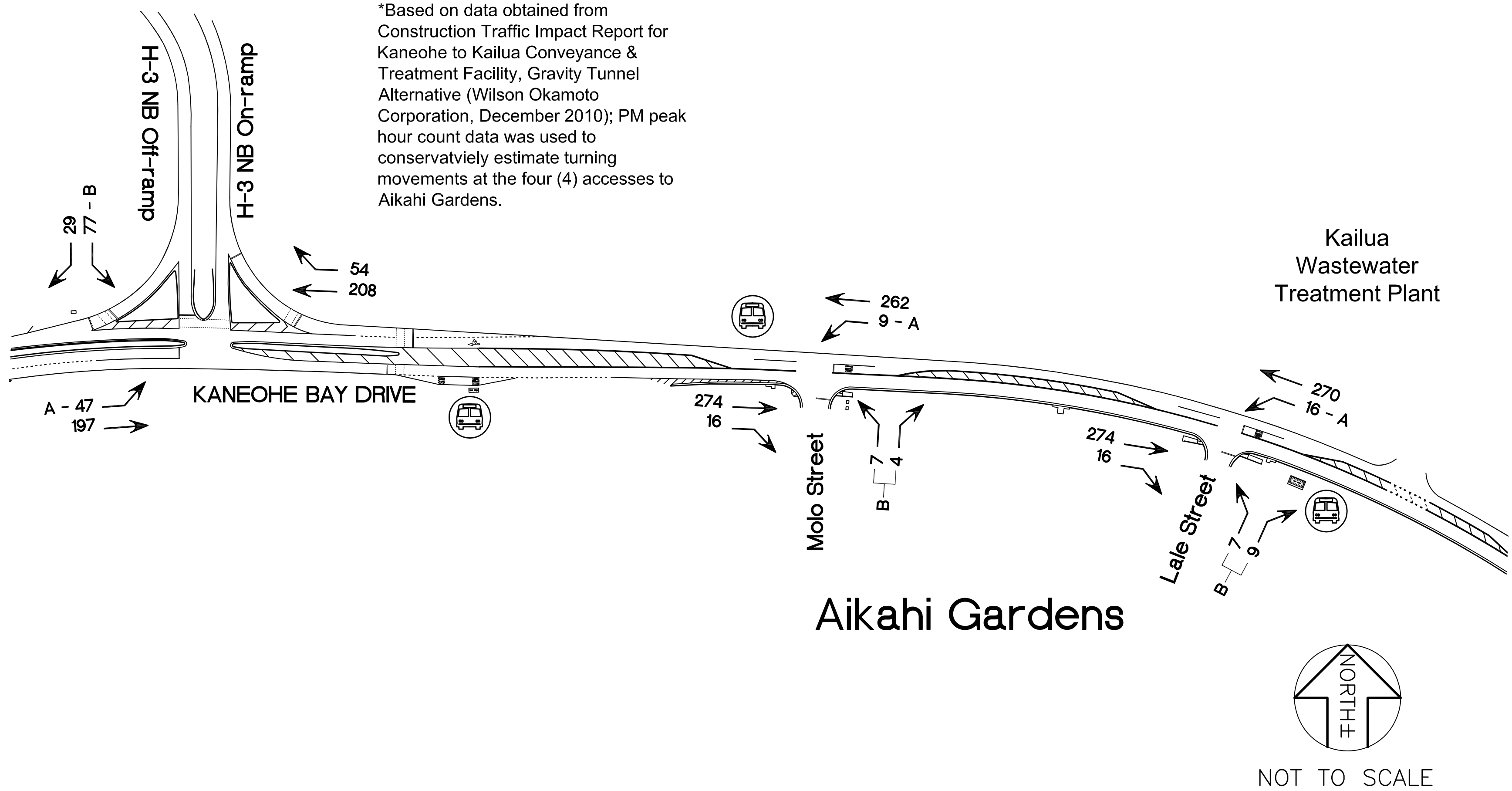
MIDDAY PEAK HOUR:
11:45 AM - 12:45 PM

*Based on data obtained from Construction Traffic Impact Report for Kaneohe to Kailua Conveyance & Treatment Facility, Gravity Tunnel Alternative (Wilson Okamoto Corporation, December 2010); PM peak hour count data was used to conservatviely estimate turning movements at the four (4) accesses to Aikahi Gardens.

LEGEND:

- TheBus Stop

X - ## = Midday Peak Hour of Traffic Volumes w/LOS X



KANEOHE/KAILUA FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
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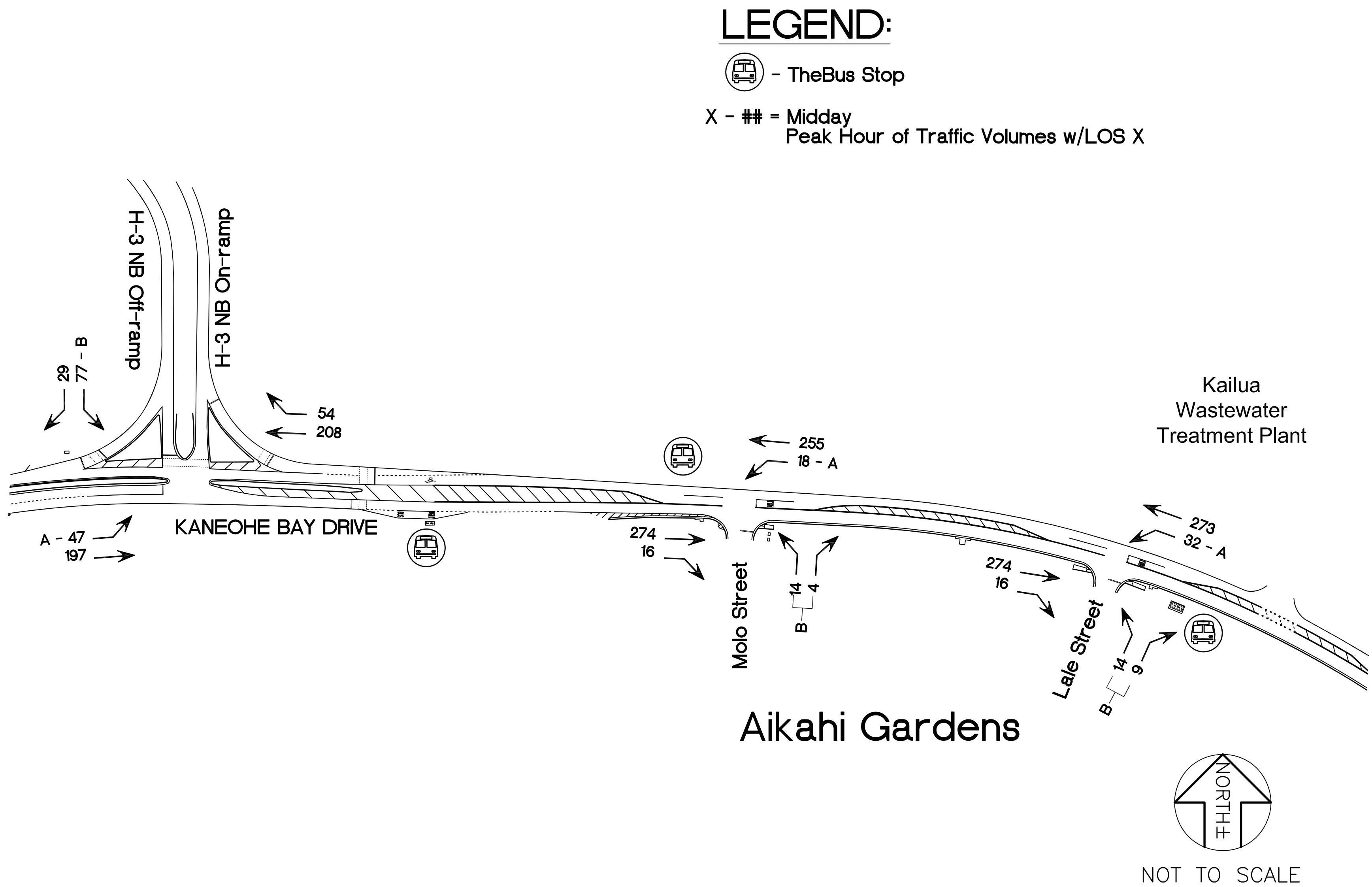
NORTH SITE EXISTING CONDITIONS

FIGURE
3



KANEOHE/KAILUA FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

NORTH SITE WITH PROJECT

FIGURE 4

TABLE 2: North Site
Level of Service Summary

Intersection	Existing Conditions (Midday) HCM Delay	v/c Ratio	LOS	With Project (Midday) HCM Delay	v/c Ratio	LOS
Kaneohe Bay Drive/H-3 On-/Off-Ramps						
EB LT	7.7	0.04	A	7.8	0.04	A
EB TH	0.0	0.13	N/A	0.0	0.13	N/A
WB TH/RT	0.0	0.17	N/A	0.0	0.17	N/A
SB LT	12.7	0.17	B	13.2	0.19	B
Kaneohe Bay Drive/Molo Street						
EB TH/RT	0.0	0.19	N/A	0.0	0.19	N/A
WB LT	7.9	0.01	A	8.0	0.02	A
WB TH	0.0	0.17	N/A	0.0	0.16	N/A
NB LT/TH	11.7	0.02	B	12.6	0.04	B
Kaneohe Bay Drive/Lale Street						
EB TH/RT	0.0	0.18	N/A	0.0	0.18	N/A
WB LT	7.9	0.01	A	7.9	0.03	A
WB TH	0.0	0.17	N/A	0.0	0.17	N/A
NB LT/TH	11.2	0.03	B	11.4	0.05	B

N/A = No LOS provided by synchro -- likely due to low delay

Traffic Control Plans

The construction plans do not contain closures of lane approaches at the H-3 Freeway On-/Off-ramp or one-lane bi-directional flow along Kaneohe Bay Drive. As such, the discussions provided in the underlined subsections of section D of the TA are no longer applicable.

Construction Management Plan

It is recommended that in addition to the recommendations provided in Section V of the TA, a CMP be prepared prior to construction.

Should you have any questions or require further information, please feel free to contact me at 533-3646.

Very truly yours,

AUSTIN, TSUTSUMI & ASSOCIATES, INC.

By

MATT K. NAKAMOTO, P.E.
Transportation Engineer

MKN:mkn

Enclosures: 1. LOS Definitions
2. Synchro Analysis Worksheets

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Enclosure 1: LOS Definitions

ENCLOSURE 1: LEVEL OF SERVICE (LOS) CRITERIA

LEVEL OF SERVICE FOR SIGNALIZED INTERSECTIONS (HCM 2000)

Level of service for signalized intersections is directly related to delay values and is assigned on that basis. Level of Service is a measure of the acceptability of delay values to motorists at a given intersection. The criteria are given in table below.

Level-of Service Criteria for Signalized Intersections

Level of Service	Control Delay per Vehicle (sec./veh.)
A	< 10.0
B	>10.0 and ≤ 20.0
C	>20.0 and ≤ 35.0
D	>35.0 and ≤ 55.0
E	>55.0 and ≤ 80.0
F	> 80.0

Delay is a complex measure, and is dependent on a number of variables, including the quality of progression, the cycle length, the green ratio, and the v/c ratio for the lane group or approach in question.

LEVEL OF SERVICE CRITERIA FOR UNSIGNALIZED INTERSECTIONS (HCM 2000)

The level of service criteria for unsignalized intersections is defined as the average control delay, in seconds per vehicle.

LOS delay threshold values are lower for two-way stop-controlled (TWSC) and all-way stop-controlled (AWSC) intersections than those of signalized intersections. This is because more vehicles pass through signalized intersections, and therefore, drivers expect and tolerate greater delays. While the criteria for level of service for TWSC and AWSC intersections are the same, procedures to calculate the average total delay may differ.

Level of Service Criteria for Two-Way Stop-Controlled Intersections

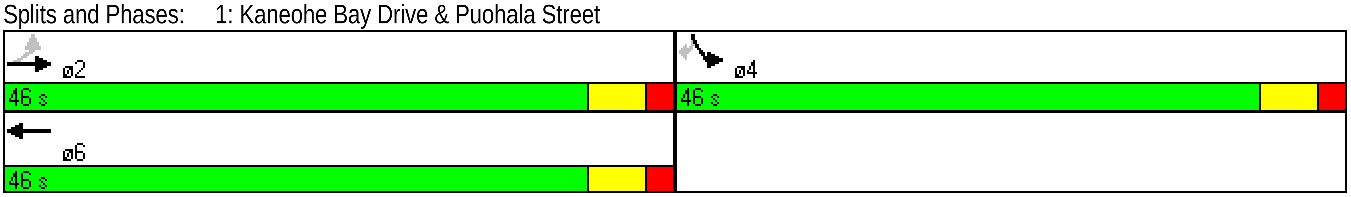
Level of Service	Average Control Delay (sec/veh)
A	≤ 10
B	>10 and ≤15
C	>15 and ≤25
D	>25 and ≤35
E	>35 and ≤50
F	> 50

Enclosure 2: Synchro Analysis Worksheets

Lane Group	EBL	EBT	WBT	SBL	SBR
Lane Configurations					
Volume (vph)	18	453	461	219	30
Turn Type	Perm				Perm
Protected Phases		2	6	4	
Permitted Phases	2				4
Detector Phase	2	2	6	4	4
Switch Phase					
Minimum Initial (s)	30.0	30.0	30.0	8.0	8.0
Minimum Split (s)	36.0	36.0	36.0	45.0	45.0
Total Split (s)	46.0	46.0	46.0	46.0	46.0
Total Split (%)	50.0%	50.0%	50.0%	50.0%	50.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	6.0	6.0	6.0	6.0	6.0
Lead/Lag					
Lead-Lag Optimize?					
Recall Mode	Min	Min	Min	None	None

Intersection Summary
Cycle Length: 92
Actuated Cycle Length: 68
Natural Cycle: 85
Control Type: Actuated-Uncoordinated

Splits and Phases: 1: Kaneohe Bay Drive & Puohala Street



Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Volume (vph)	18	453	461	292	219	30
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	6.0	6.0	6.0		6.0	6.0
Lane Util. Factor	1.00	0.95	*0.50		1.00	1.00
Frt	1.00	1.00	0.94		1.00	0.85
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1770	3539	1754		1770	1583
Flt Permitted	0.10	1.00	1.00		0.95	1.00
Satd. Flow (perm)	185	3539	1754		1770	1583
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	20	492	501	317	238	33
RTOR Reduction (vph)	0	0	18	0	0	15
Lane Group Flow (vph)	20	492	800	0	238	18
Turn Type	Perm					Perm
Protected Phases		2	6		4	
Permitted Phases	2					4
Actuated Green, G (s)	40.2	40.2	40.2		15.7	15.7
Effective Green, g (s)	40.2	40.2	40.2		15.7	15.7
Actuated g/C Ratio	0.59	0.59	0.59		0.23	0.23
Clearance Time (s)	6.0	6.0	6.0		6.0	6.0
Vehicle Extension (s)	4.0	4.0	4.0		4.0	4.0
Lane Grp Cap (vph)	110	2095	1038		409	366
v/s Ratio Prot		0.14	c0.46		c0.13	
v/s Ratio Perm	0.11					0.01
v/c Ratio	0.18	0.23	0.77		0.58	0.05
Uniform Delay, d1	6.3	6.6	10.4		23.2	20.3
Progression Factor	1.00	1.00	1.00		1.00	1.00
Incremental Delay, d2	1.1	0.1	3.8		2.5	0.1
Delay (s)	7.4	6.6	14.2		25.7	20.4
Level of Service	A	A	B		C	C
Approach Delay (s)		6.7	14.2		25.0	
Approach LOS		A	B		C	

Intersection Summary			
HCM Average Control Delay	13.6	HCM Level of Service	B
HCM Volume to Capacity ratio	0.72		
Actuated Cycle Length (s)	67.9	Sum of lost time (s)	12.0
Intersection Capacity Utilization	47.1%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		✣			✣			✣			✣	
Volume (veh/h)	0	7	6	20	10	9	2	217	22	12	223	8
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	0	8	7	22	11	10	2	236	24	13	242	9
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)								811				
pX, platoon unblocked												
vC, conflicting volume	540	537	247	535	529	248	251			260		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	540	537	247	535	529	248	251			260		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	100	98	99	95	98	99	100			99		
cM capacity (veh/h)	435	445	792	442	450	791	1314			1305		

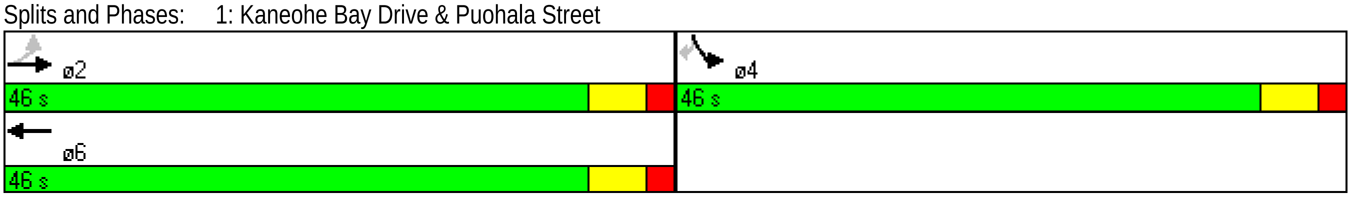
Direction, Lane #	EB 1	WB 1	NB 1	SB 1
Volume Total	14	42	262	264
Volume Left	0	22	2	13
Volume Right	7	10	24	9
cSH	558	495	1314	1305
Volume to Capacity	0.03	0.09	0.00	0.01
Queue Length 95th (ft)	2	7	0	1
Control Delay (s)	11.6	13.0	0.1	0.5
Lane LOS	B	B	A	A
Approach Delay (s)	11.6	13.0	0.1	0.5
Approach LOS	B	B		

Intersection Summary			
Average Delay	1.5		
Intersection Capacity Utilization	35.7%	ICU Level of Service	A
Analysis Period (min)	15		

Lane Group	EBL	EBT	WBT	SBL	SBR
Lane Configurations					
Volume (vph)	21	453	461	219	33
Turn Type	Perm				Perm
Protected Phases		2	6	4	
Permitted Phases	2				4
Detector Phase	2	2	6	4	4
Switch Phase					
Minimum Initial (s)	30.0	30.0	30.0	8.0	8.0
Minimum Split (s)	36.0	36.0	36.0	45.0	45.0
Total Split (s)	46.0	46.0	46.0	46.0	46.0
Total Split (%)	50.0%	50.0%	50.0%	50.0%	50.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	6.0	6.0	6.0	6.0	6.0
Lead/Lag					
Lead-Lag Optimize?					
Recall Mode	Min	Min	Min	None	None

Intersection Summary
Cycle Length: 92
Actuated Cycle Length: 68
Natural Cycle: 85
Control Type: Actuated-Uncoordinated

Splits and Phases: 1: Kaneohe Bay Drive & Puohala Street



Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Volume (vph)	21	453	461	292	219	33
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	6.0	6.0	6.0		6.0	6.0
Lane Util. Factor	1.00	0.95	*0.50		1.00	1.00
Frt	1.00	1.00	0.94		1.00	0.85
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1770	3539	1754		1770	1583
Flt Permitted	0.10	1.00	1.00		0.95	1.00
Satd. Flow (perm)	185	3539	1754		1770	1583
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	23	492	501	317	238	36
RTOR Reduction (vph)	0	0	18	0	0	16
Lane Group Flow (vph)	23	492	800	0	238	20
Turn Type	Perm					Perm
Protected Phases		2	6		4	
Permitted Phases	2					4
Actuated Green, G (s)	40.2	40.2	40.2		15.7	15.7
Effective Green, g (s)	40.2	40.2	40.2		15.7	15.7
Actuated g/C Ratio	0.59	0.59	0.59		0.23	0.23
Clearance Time (s)	6.0	6.0	6.0		6.0	6.0
Vehicle Extension (s)	4.0	4.0	4.0		4.0	4.0
Lane Grp Cap (vph)	110	2095	1038		409	366
v/s Ratio Prot		0.14	c0.46		c0.13	
v/s Ratio Perm	0.12					0.01
v/c Ratio	0.21	0.23	0.77		0.58	0.05
Uniform Delay, d1	6.4	6.6	10.4		23.2	20.3
Progression Factor	1.00	1.00	1.00		1.00	1.00
Incremental Delay, d2	1.3	0.1	3.8		2.5	0.1
Delay (s)	7.7	6.6	14.2		25.7	20.4
Level of Service	A	A	B		C	C
Approach Delay (s)		6.7	14.2		25.0	
Approach LOS		A	B		C	

Intersection Summary			
HCM Average Control Delay	13.6	HCM Level of Service	B
HCM Volume to Capacity ratio	0.72		
Actuated Cycle Length (s)	67.9	Sum of lost time (s)	12.0
Intersection Capacity Utilization	47.1%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	7	6	23	10	9	2	217	25	12	223	8
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	0	8	7	25	11	10	2	236	27	13	242	9
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)								811				
pX, platoon unblocked												
vC, conflicting volume	542	540	247	537	531	249	251			263		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	542	540	247	537	531	249	251			263		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	100	98	99	94	98	99	100			99		
cM capacity (veh/h)	434	443	792	441	449	789	1314			1301		

Direction, Lane #	EB 1	WB 1	NB 1	SB 1
Volume Total	14	46	265	264
Volume Left	0	25	2	13
Volume Right	7	10	27	9
cSH	556	489	1314	1301
Volume to Capacity	0.03	0.09	0.00	0.01
Queue Length 95th (ft)	2	8	0	1
Control Delay (s)	11.6	13.1	0.1	0.5
Lane LOS	B	B	A	A
Approach Delay (s)	11.6	13.1	0.1	0.5
Approach LOS	B	B		

Intersection Summary			
Average Delay	1.5		
Intersection Capacity Utilization	35.9%	ICU Level of Service	A
Analysis Period (min)	15		

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Volume (veh/h)	47	197	208	54	77	29
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	51	214	226	59	84	32
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						4
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			280			
pX, platoon unblocked	0.87				0.87	0.87
vC, conflicting volume	226				572	255
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	31				429	64
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	96				83	96
cM capacity (veh/h)	1372				486	867

Direction, Lane #	EB 1	EB 2	WB 1	SB 1
Volume Total	51	214	285	115
Volume Left	51	0	0	84
Volume Right	0	0	59	32
cSH	1372	1700	1700	670
Volume to Capacity	0.04	0.13	0.17	0.17
Queue Length 95th (ft)	3	0	0	15
Control Delay (s)	7.7	0.0	0.0	12.7
Lane LOS	A			B
Approach Delay (s)	1.5		0.0	12.7
Approach LOS				B

Intersection Summary			
Average Delay	2.8		
Intersection Capacity Utilization	31.8%	ICU Level of Service	A
Analysis Period (min)	15		

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Volume (veh/h)	274	16	9	262	7	4
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	298	17	10	285	8	4
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage veh)						
Upstream signal (ft)	460					
pX, platoon unblocked			0.89		0.89	0.89
vC, conflicting volume			315		611	307
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			174		505	164
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			99		98	99
cM capacity (veh/h)			1237		470	791

Direction, Lane #	EB 1	WB 1	WB 2	NB 1
Volume Total	315	10	285	12
Volume Left	0	10	0	8
Volume Right	17	0	0	4
cSH	1700	1237	1700	552
Volume to Capacity	0.19	0.01	0.17	0.02
Queue Length 95th (ft)	0	1	0	2
Control Delay (s)	0.0	7.9	0.0	11.7
Lane LOS		A		B
Approach Delay (s)	0.0	0.3		11.7
Approach LOS				B

Intersection Summary			
Average Delay	0.3		
Intersection Capacity Utilization	25.4%	ICU Level of Service	A
Analysis Period (min)	15		

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Volume (veh/h)	265	13	16	270	7	9
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	288	14	17	293	8	10
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage veh)						
Upstream signal (ft)	938					
pX, platoon unblocked			0.93		0.93	0.93
vC, conflicting volume			302		623	295
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			211		557	203
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			99		98	99
cM capacity (veh/h)			1263		454	783

Direction, Lane #	EB 1	WB 1	WB 2	NB 1
Volume Total	302	17	293	17
Volume Left	0	17	0	8
Volume Right	14	0	0	10
cSH	1700	1263	1700	594
Volume to Capacity	0.18	0.01	0.17	0.03
Queue Length 95th (ft)	0	1	0	2
Control Delay (s)	0.0	7.9	0.0	11.2
Lane LOS		A		B
Approach Delay (s)	0.0	0.4		11.2
Approach LOS				B

Intersection Summary			
Average Delay	0.5		
Intersection Capacity Utilization	24.7%	ICU Level of Service	A
Analysis Period (min)	15		

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Volume (veh/h)	47	197	208	57	80	29
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	51	214	226	62	87	32
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						4
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			280			
pX, platoon unblocked	0.96				0.96	0.96
vC, conflicting volume	226				573	257
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	167				530	199
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	96				81	96
cM capacity (veh/h)	1348				468	804

Direction, Lane #	EB 1	EB 2	WB 1	SB 1
Volume Total	51	214	288	118
Volume Left	51	0	0	87
Volume Right	0	0	62	32
cSH	1348	1700	1700	638
Volume to Capacity	0.04	0.13	0.17	0.19
Queue Length 95th (ft)	3	0	0	17
Control Delay (s)	7.8	0.0	0.0	13.2
Lane LOS	A			B
Approach Delay (s)	1.5		0.0	13.2
Approach LOS				B

Intersection Summary			
Average Delay	2.9		
Intersection Capacity Utilization	32.2%	ICU Level of Service	A
Analysis Period (min)	15		

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Volume (veh/h)	274	16	18	255	14	4
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	298	17	20	277	15	4
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage veh)						
Upstream signal (ft)	460					
pX, platoon unblocked			0.97		0.97	0.97
vC, conflicting volume			315		623	307
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			279		596	270
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			98		97	99
cM capacity (veh/h)			1229		449	750

Direction, Lane #	EB 1	WB 1	WB 2	NB 1
Volume Total	315	20	277	20
Volume Left	0	20	0	15
Volume Right	17	0	0	4
cSH	1700	1229	1700	493
Volume to Capacity	0.19	0.02	0.16	0.04
Queue Length 95th (ft)	0	1	0	3
Control Delay (s)	0.0	8.0	0.0	12.6
Lane LOS		A		B
Approach Delay (s)	0.0	0.5		12.6
Approach LOS				B

Intersection Summary			
Average Delay	0.6		
Intersection Capacity Utilization	25.4%	ICU Level of Service	A
Analysis Period (min)	15		

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Volume (veh/h)	265	13	32	273	14	9
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	288	14	35	297	15	10
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage veh)						
Upstream signal (ft)	938					
pX, platoon unblocked						
vC, conflicting volume			302		661	295
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			302		661	295
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			97		96	99
cM capacity (veh/h)			1259		418	749

Direction, Lane #	EB 1	WB 1	WB 2	NB 1
Volume Total	302	35	297	25
Volume Left	0	35	0	15
Volume Right	14	0	0	10
cSH	1700	1259	1700	506
Volume to Capacity	0.18	0.03	0.17	0.05
Queue Length 95th (ft)	0	2	0	4
Control Delay (s)	0.0	7.9	0.0	12.5
Lane LOS		A		B
Approach Delay (s)	0.0	0.8		12.5
Approach LOS				B

Intersection Summary			
Average Delay	0.9		
Intersection Capacity Utilization	31.4%	ICU Level of Service	A
Analysis Period (min)	15		

TRAFFIC ASSESSMENT
KANEOHE/KAILUA FORCE MAIN NO. 2
Kaneohe/Kailua, Oahu, Hawaii

FINAL

December 8, 2010

Prepared for:

City and County of Honolulu
Department of Design and Construction
650 South King Street, 11th Floor
Honolulu, Hawaii 96813

Austin, Tsutsumi & Associates, Inc.
Civil Engineers • Surveyors
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817-5031
Telephone: (808) 533-3646
Facsimile: (808) 526-1267
E-mail: atahnl@atahawaii.com
Honolulu • Wailuku • Hilo, Hawaii

TRAFFIC ASSESSMENT
KANEOHE/KAILUA FORCE MAIN NO. 2

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APPENDICES

AUSTIN, TSUTSUMI & ASSOCIATES, INC. CIVIL ENGINEERS • SURVEYORS
CONTINUING THE ENGINEERING PRACTICE FOUNDED BY H. A. R. AUSTIN IN 1934

KENNETH K. KUROKAWA, P.E.
TERRANCE S. ARASHIRO, P.E.
DONOHUE M. FUJII, P.E.
STANLEY T. WATANABE
IVAN K. NAKATSUKA, P.E.
ADRIENNE W. L. H. WONG, P.E., LEED AP

FINAL

TRAFFIC ASSESSMENT
KANEOHE/KAILUA FORCE MAIN NO. 2
Kaneohe, Oahu, Hawaii

I. INTRODUCTION

This report will consider the traffic impacts of and provide recommendations for the Kaneohe/Kailua Force Main No. 2 project (hereinafter referred to as "Project"). The Project will establish a sewer line between the Kailua Regional Wastewater Treatment Plant ("North Site") and the Kaneohe Wastewater Pre-Treatment Facility ("South Site"). Both sites will serve as staging areas for construction. See Figure 1 for Project Location.

The project will be divided into three (3) segments:

1. Segment A – between the South Site and Kaneohe bay; open trench method will be used.
2. Segment B – through Kaneohe Bay; one of two alternatives will be used: 1) Horizontal Directional Drilling (HDD), and 2) Tunneling.
3. Segment C – between the North Site and the H-3 Freeway Interchange; open trench method will be used.

Relative to traffic operations, the Project will affect the North and South Sites in the following ways:

<u>North Site</u>

1. Trench through the H-3 Freeway On/Off-Ramp/Kaneohe Bay Drive intersection, but only close a single approach at a time.

REPLY TO:
501 SUMNER STREET, SUITE 521 • HONOLULU, HAWAII 96817-5031
PHONE (808) 533-3646 • FAX (808) 526-1267
EMAIL : atahnl@atahawaii.com

OFFICES IN:
HONOLULU, HAWAII
WAILUKU, MAUI, HAWAII
HILO, HAWAII

2. Reduce the flow of traffic along Kaneohe Bay Drive to a minimum of a single, bi-directional lane near the construction area[1].

3. Route as many as six (6) heavy vehicles per hour between the North Site and the Waianae Landfill.

4. Occasionally transport equipment between the North and South Sites.

South Site

1. Route as many as six (6) heavy vehicles per hour through Kulauli Street and Puohala Street – and between the South Site and the North Site or the Waianae Landfill.

2. Occasionally transport equipment between the North and South Sites.

A. Study Methodology

This study will address the following:

1. Existing traffic operating conditions at key locations within the study area,

2. Consideration of the impacts of construction activities, and

3. Provide recommendations to mitigate impacts resulting from construction activities (if any).

II. NORTH SITE CONDITIONS AND ANALYSIS

A. Roadway System

Kaneohe Bay Drive serves as a major collector roadway between Kaneohe and Kailua. In the vicinity of the North Site, it is an east-west two-lane city collector roadway with a posted speed limit of 35 mph. A median storage lane is provided for left-turns at its intersections.

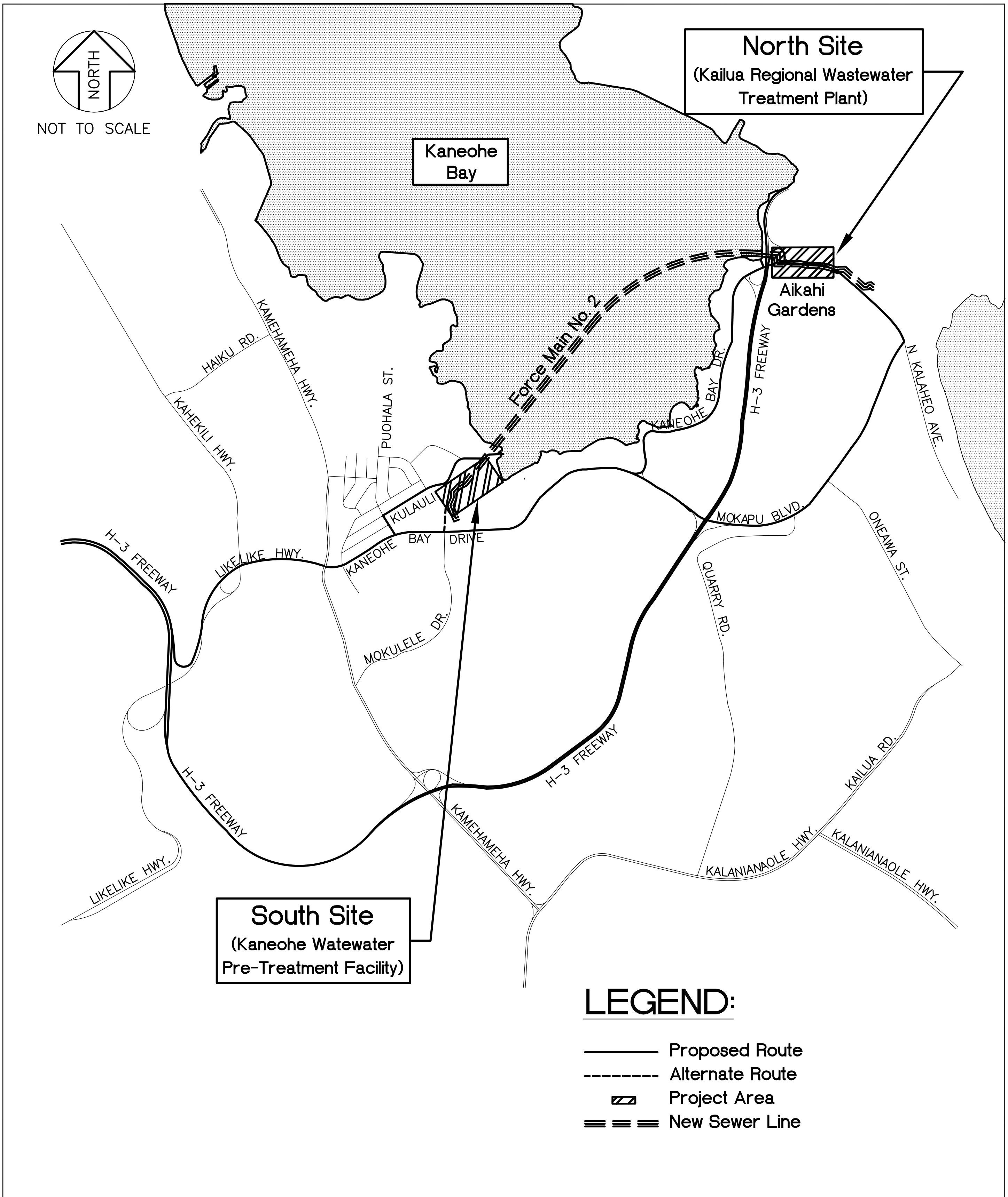
Molo Street and Lale Street serves as two (2) of four (4) driveways into the Aikahi Gardens townhouse units. The parking area provides internal connectivity to all four of the driveways.

[1] The current lane configuration offers a single lane in either direction, and a median turning lane.

The H-3 Freeway On- and Off-ramps provide access to the H-3 Freeway. The ramps' intersections with Kaneohe Bay drive are un-signalized.

B. Bus Routes

Route 56 provides local access between Kailua and Kaneohe, as well as regional access to downtown and the Ala Moana Shopping Center. Three (3) Bus stops are situated along Kaneohe Bay Drive near the North Site. See Figure 1 for project locations.



KAILUA/KANEOHE FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

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PROJECT LOCATION

FIGURE
1

C. Existing Traffic Conditions and Observations

Manual turning movement counts and field observations were conducted on Thursday, October 28, 2009 during a time when all schools were known to have been in-session at the following unsignalized intersections:

1. Kaneohe Bay Drive/H-3 Northbound On-/Off-Ramp
2. Molo Street/Kaneohe Bay Drive
3. Lale Street/Kaneohe Bay Drive

The data would indicate that the AM and PM peak hours of traffic occurred between 7:00-8:00 AM and 4:30-5:30 PM[2]. See Appendix A for count data.

Average Daily Traffic (ADT) counts from the year 2007 were obtained from the Hawaii Department of Transportation (HDOT); these counts were used to determine that the busiest hour during construction times would be 2:00-3:00 PM (School Peak).

During the AM and PM peak hours, traffic generally flowed smoothly along Kaneohe Bay Drive. Traffic turning onto Kaneohe Bay Drive near the north site experienced very little delay during the AM and PM peak hours, as there were adequate gaps in the flow of traffic.

See Figure 2 for traffic count data, bus stop locations, and an overall depiction of roadway geometrics. See Figure 3 for a graph showing the daily fluctuation of traffic based on the 2007 HDOT traffic counts at Kaneohe Bay Drive, near Molo Street.

[2] Although construction will be limited to between 8:30 and 3:00 on weekdays, the AM and PM peak hours were counted to observe the busiest conditions possible.

DATE OF COUNTS:
THURSDAY, OCTOBER 28TH, 2009

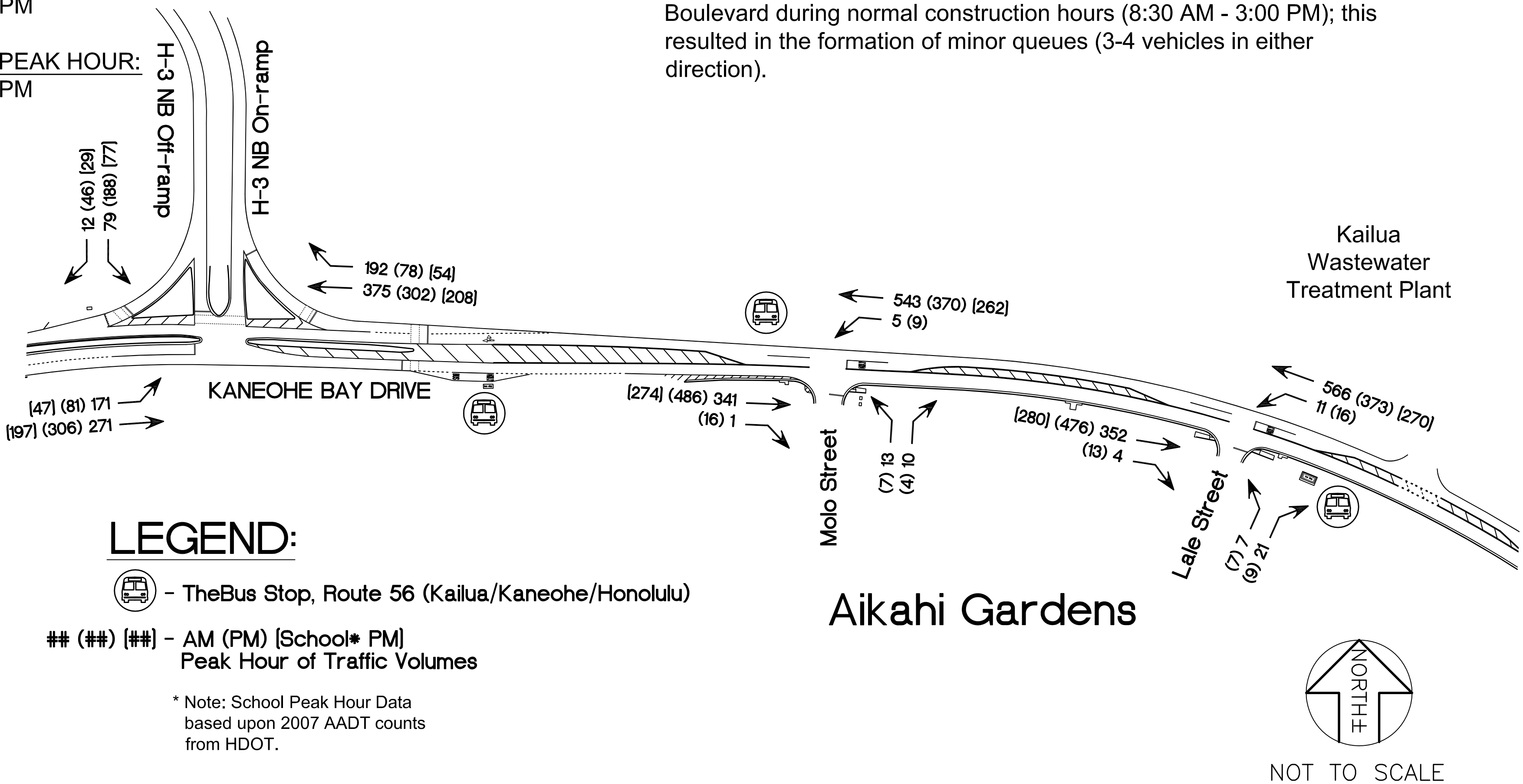
AM PEAK HOUR:
7:00 -8:00 AM

PM PEAK HOUR:
4:30-5:30 PM

SCHOOL PEAK HOUR:
2:00-3:00 PM

Observations:

1. No congestion observed during the AM or PM peak hours of traffic.
2. On 2/24/10, it was observed that Kaneohe Bay Drive was closed to a single, bi-directional lane near its southwest intersection with Mokapu Boulevard during normal construction hours (8:30 AM - 3:00 PM); this resulted in the formation of minor queues (3-4 vehicles in either direction).



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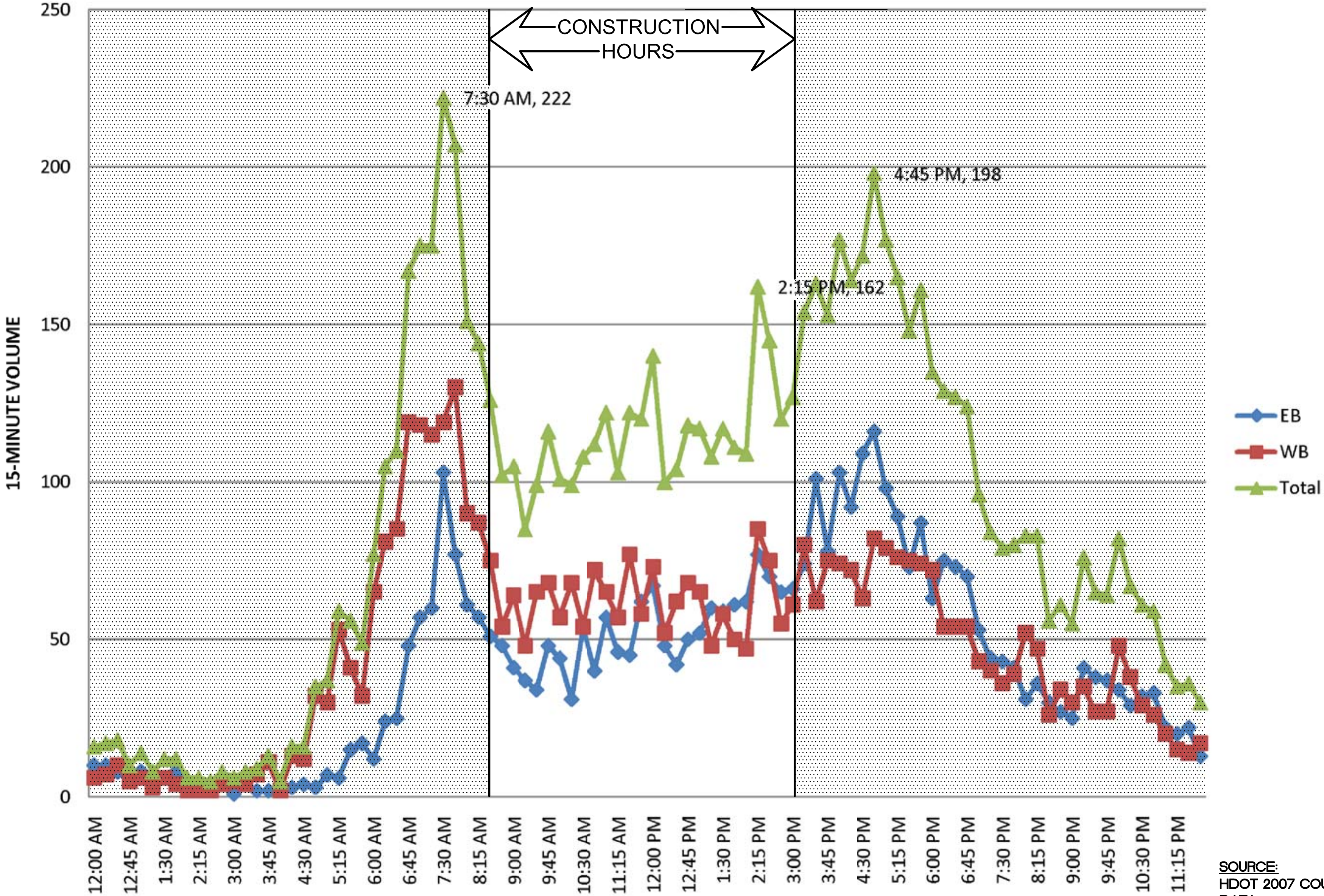
CITY AND COUNTY OF HONOLULU

NORTH SITE EXISTING CONDITIONS

FIGURE 2



SOURCE:
HDOT 2007 COUNT DATA

KAILUA/KANEOHE FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

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24-HOUR HDOT COUNTS - KANEOHE BAY DRIVE NEAR MOLO STREET

FIGURE 3

D. North Site Construction

As stated in the introduction, the primary impacts of the project on the North Site would be the narrowing of the travelway along Kaneohe Bay Drive and restriction of turning movements onto and off of the H-3 On- and Off-Ramp near the site. See Figure 4 for volumes and possible construction phasing.

Project-related heavy vehicle traffic was assumed to occur at a rate of six (6) vehicles/hour and travel to and from the Waianae Landfill or South Site during construction hours. Given that this is a relatively small volume occurring outside the peak hours of traffic, the impact of these trucks should be minimal relative to traffic operations.

While construction activities along the median could block left-turn access to and from some of the Aikahi Gardens access roads, the impact is anticipated to be minimal, provided that access is maintained to at least two (2) of the roads. This is due to the fact that all access roads to the Aikahi Gardens are internally connected.

<u>One-Lane, Bi-Directional Flow along Kaneohe Bay Drive</u>

It is unlikely that significant congestion will occur along Kaneohe Bay Drive; this is evidenced by the following facts:

1. ATA observed construction-related one-lane, bi-directional flow along Kaneohe Bay Drive near its southwest intersection with Mokapu Boulevard between 12:00 PM and 3:00 PM on February 24, 2010; the maximum queue observed was four (4) vehicles. However, no counts were performed at this location.

2. As shown in Figure 2, the highest likely bi-directional flow near the north site during construction hours has been measured to be **550 vehicles per hour** during the School Peak. In lieu of literature and standard analytical procedures for this type of flow, ATA used a traffic count along a roadway with similar characteristics – South Kihei Road in Kihei, Maui which was taken on March 9, 2010 to simulate the type of traffic which would occur in this area during construction operations. During this count, a bi-directional

single-lane flow rate of approximately **660 vehicles per hour** was observed to occur; maximum queues of seven (7) to ten (10) vehicles in either direction were observed.

Closure of Lane Approaches at H-3 Freeway On-/Off-Ramp

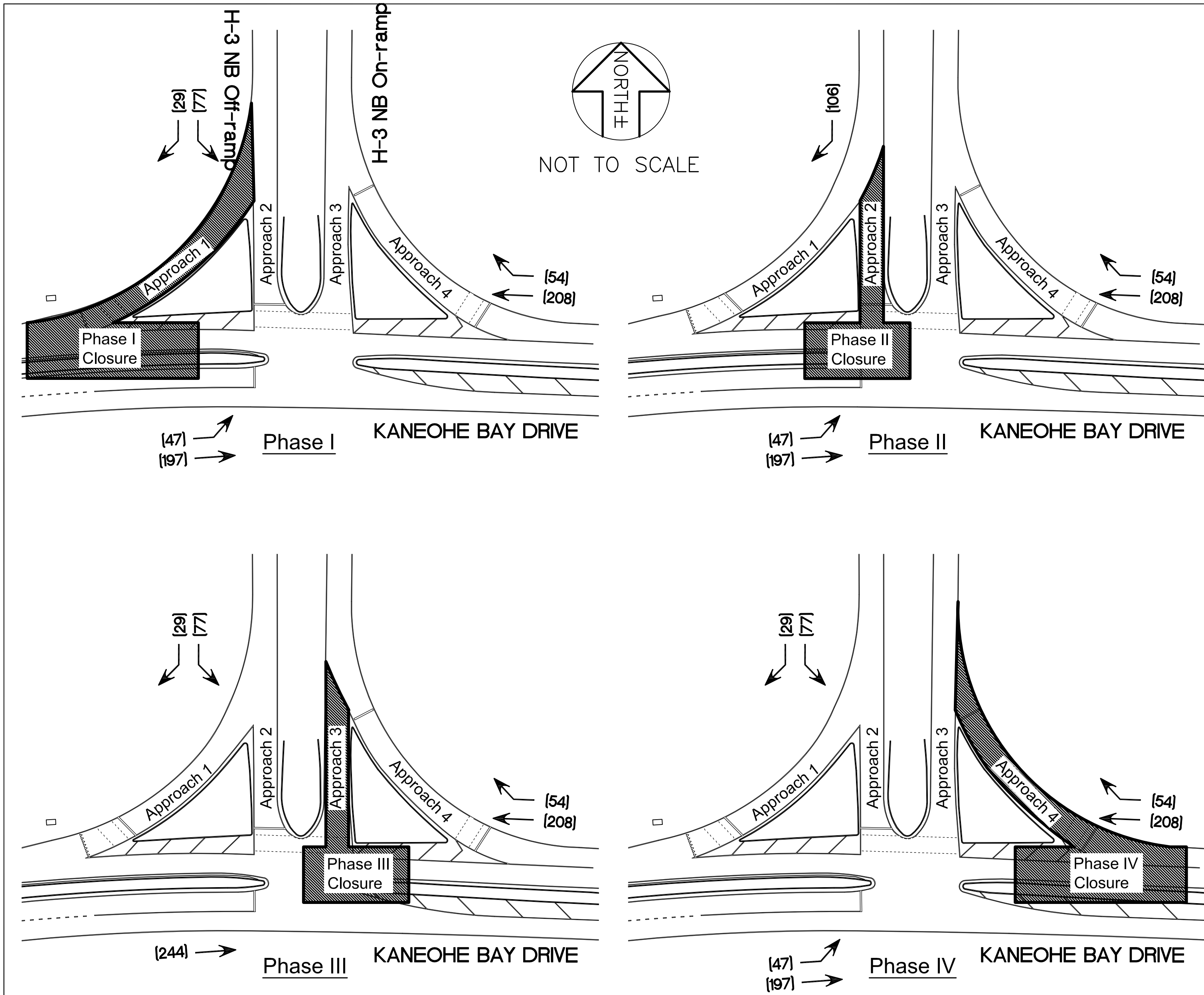
The worst-case scenario at this intersection would be its operating similarly to an all-way stop – where the westbound, eastbound, and southbound approaches would be funneled into mutually exclusive time bins (i.e. phase 1: westbound movement, phase 2: eastbound movement, phase 3: southbound movement).

Similar to the discussion of one-lane, bi-directional flow along Kaneohe Bay Drive, the sum of all movements' traffic at this intersection during the School Peak Hour would equate to 612 vehicles – less than the 660 vehicles/hour counted during the similar Kihei count discussed previously. Therefore, while some congestion could occur, it is unlikely that traffic queues would extend onto the H-3 Freeway. However, it is recommended as a precaution that traffic control officers direct traffic in a manner preferential to those exiting the H-3 Freeway. See Figure 4 for ramp crossing illustrations.

Bus Routes

It is recommended that accommodations be made to ensure the continuing operation of bus route 56, as it is the only bus route that services this area.

If bus stops will be obstructed as a result of construction operations, Oahu Transit Services (OTS) should be notified.



Notes:

1. This figure is NOT INTENDED TO SERVE AS A TRAFFIC CONTROL PLAN. Rather, it has been included to show the maximum extent of closure at the H-3 Freeway On-/Off-Ramp resulting from trench work along Kaneohe Bay Drive for the North Site.

2. It is assumed that ultimately, access to the H-3 freeway will be maintained; however, specific turning movements could be affected.

LEGEND:

(##) – (School*) Peak Hour of Traffic Volumes

* Note: School Peak Hour Data based upon 2007 AADT counts from HDOT.

KAILUA/KANEOHE FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

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NORTH SITE RAMP APPROACH CROSSINGS

FIGURE

4

III. SOUTH SITE CONDITIONS AND ANALYSIS

A. Roadway System

Kaneohe Bay Drive serves as a major collector roadway between Kaneohe and Kailua. Near the Bayview Golf Course, it is a two-lane road with turning lanes at its major intersections, but widens to four (4) lanes near Puohala Street.

Puohala Street is a two-way, two-lane county collector road with a posted speed limit of 25 mph. A traffic signal is provided at its intersection with Kaneohe Bay Drive.

Kulauli Street is a two-way, two-lane county local road with a posted speed limit of 25 mph.

B. Bus Routes

Routes 55, 56, and 65 provide local access between Kailua and Kaneohe, as well as regional access to downtown and the Ala Moana Shopping Center. Route 56 traverses Puohala Street.

Route 85 provides access between Kailua, Kaneohe, downtown, and the University of Hawaii and Manoa.

Route PH5 provides access between Kailua, Kaneohe, and Pearl Harbor via the H-3 Freeway.

C. Existing Traffic Conditions and Observations

Average Daily Traffic (ADT) counts from the year 2007 were obtained from the Hawaii Department of Transportation (HDOT); these counts were used to determine that the busiest hour during construction times – 2:00-3:00 PM (School Peak).

Manual turning movement counts and field observations for the school peak hour were conducted on Tuesday, February 23, 2010 during a time when all schools were known to have been in-session at the Kaneohe Bay Drive/Puohala Street intersection. Weekday Midday, AM, and PM peak hour traffic were obtained from other sources[3], and have been included for informational purposes. See Appendix A for count data.

See Figure 5 for traffic count data, bus stop locations, and an overall depiction of roadway geometrics. See Figure 6 for a graph showing the daily fluctuation of traffic based on the 2007 HDOT traffic counts at Kaneohe Bay Drive, near Puohala Street.

D. South Site Construction

The only traffic-related impact of the project on the South Site would be the routing of approximately six (6) heavy vehicles/hour through the local and collector roadways near the site.

Two (2) access routes are proposed:

1. Proposed Route – Access to Kaneohe Bay Drive provided through Kulauli Street and Puohala Street, or
2. Bayview Route (Alternate) – Access to Kaneohe Bay Drive provided through the existing Bayview Golf Course entrance/exit. This alternative would incur significant additional costs as a result of:
    a. The construction of a new approximately 0.3-mile segment through the existing Bayview Golf Course, which would include a stream crossing. This would necessitate the upgrading of the existing bridge or the creation of a new bridge if the existing bridge is found to be inadequate, and
    b. Land acquisition or easement through Bayview Golf Course.

The traffic impact of the Bayview Route would be relatively limited due to the low volume of heavy vehicles planned; therefore no further discussion will be provided.

See Figure 7 for a depiction of the two (2) routes.

[3] AM and PM peak hour volumes were obtained from an October 28, 2009 count for the City and County of Honolulu, Department of Transportation Services Traffic Signal Optimization, Phase 3 project. Midday peak hour volumes were obtained from a November 23, 2010 count conducted by Wilson Okamoto Corporation.

DATE OF COUNTS:
TUESDAY, FEBRUARY 23rd, 2010

AM PEAK HOUR:
7:00-8:00 AM

MIDDAY PEAK HOUR:
11:00 AM - 12:00 PM

SCHOOL PEAK HOUR
2:00 PM-3:00 PM

PM PEAK HOUR:
4:30-5:30 PM

LEGEND:

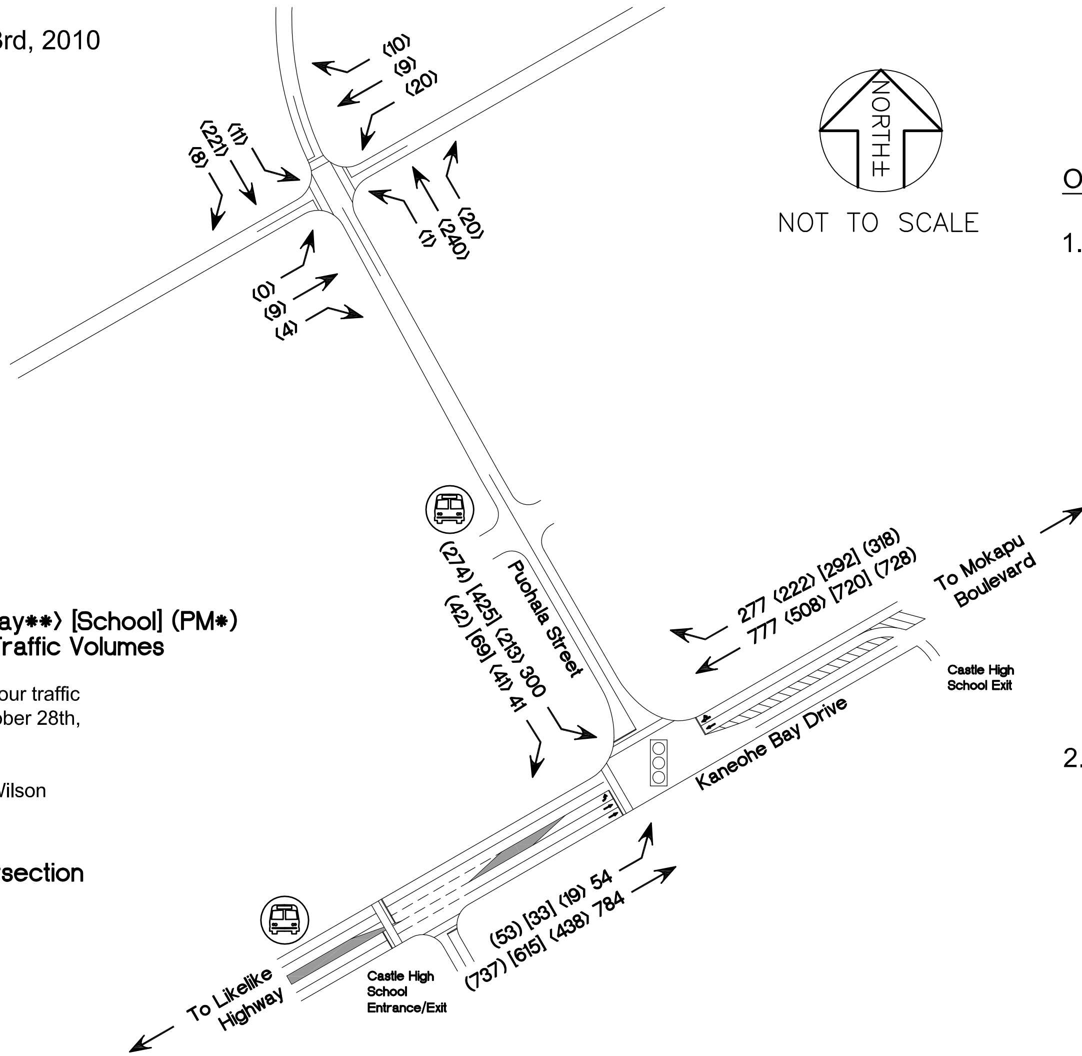
- TheBus Stop

‹##› [##] (##)- AM* ‹Midday**› [School] (PM*)
Peak Hour of Traffic Volumes

*AM and PM Peak Hour traffic counts taken on October 28th, 2009.

**Data Supplied by Wilson Okamoto, Inc.

- Signalized Intersection



Observations:

1. Heavy congestion observed along Kaneohe Bay Drive between 2:30 and 3:00 PM, primarily due to Castle High School's students being released. Congestion occurred between Likelike Highway and Moakaka Place (approx. 6000 feet eastward). The primary cause was observed to be pedestrian traffic and drop-off/pick-up activities along Kaneohe Bay Drive and school driveways. No queue build-up was observed along Puohala Street during this period.
2. During the PM peak hour, traffic flowed relatively smoothly along Kaneohe Bay Drive. However, vehicles turning left from Aumoku Street onto Kaneohe Bay Drive had difficulty.

KANEOHE/KAILUA FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
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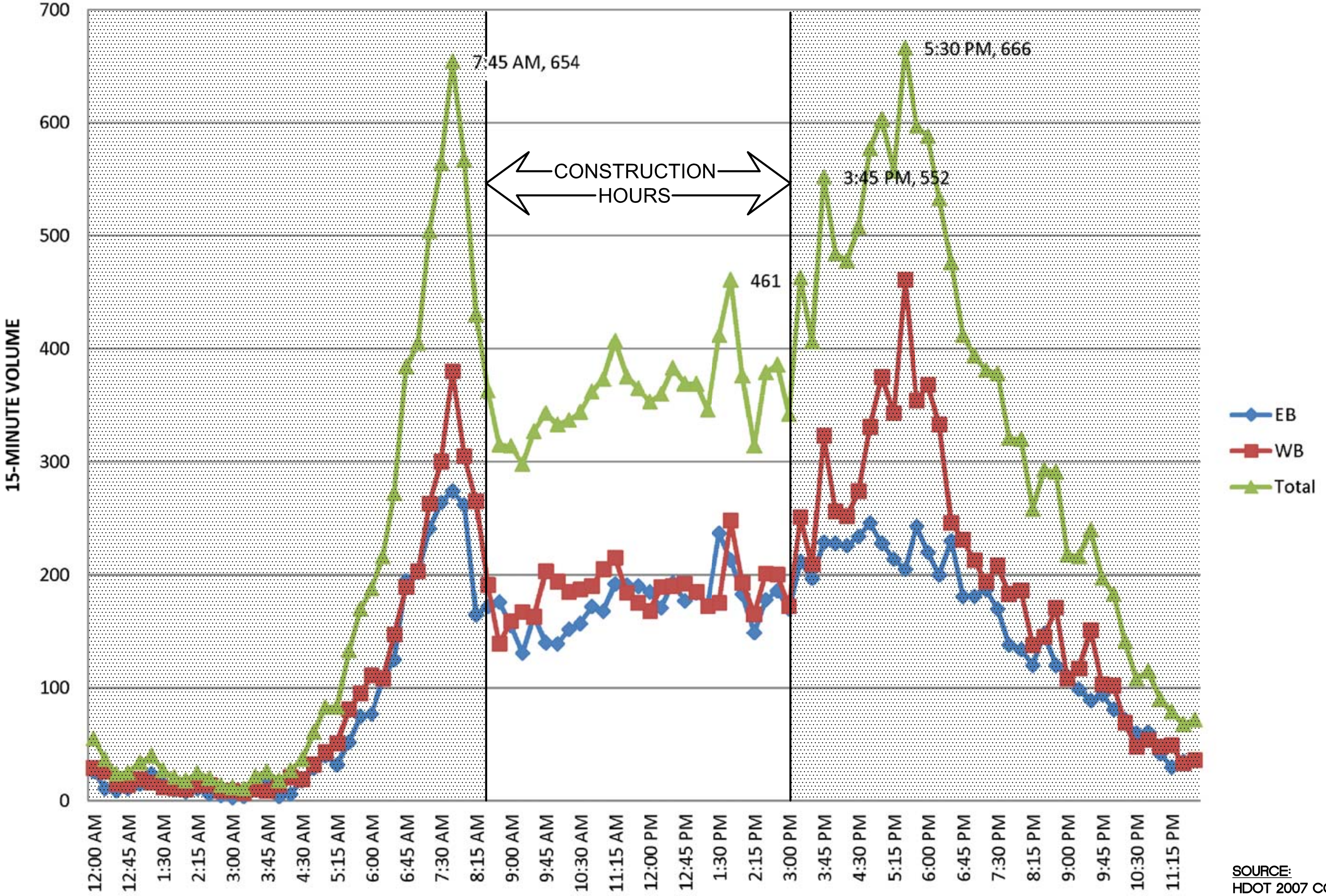
SOUTH SITE EXISTING CONDITIONS

FIGURE
5



SOURCE:
HDOT 2007 COUNT DATA

KAILUA/KANEOHE FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
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24-HOUR HDOT COUNTS - KANEOHE BAY DRIVE NEAR PUOHALA STREET

FIGURE
6

KAILUA/KANEOHE FORCE MAIN NO. 2
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SOUTH SITE HEAVY VEHICLE ROUTE

FIGURE 7

Traffic Operations

As mentioned earlier, congestion occurs along Kaneohe Bay Drive during the school peak. However, the addition of six (6) heavy vehicles/hour will only have a marginal impact on traffic operations along Puohala Street and Kaneohe Bay Drive.

The primary consideration when using the Kulauli Street/Puohala Street access route would be the potential for conflicts between heavy vehicles. It is recommended that the construction-related heavy vehicles schedule their trips as to have entering heavy vehicles avoid crossing paths of exiting heavy vehicles when traversing Kulauli Street an Puohala Street. This will minimize the need for delay-causing truck reversing.

In addition, TheBus route 56 turns on/off of Puohala Street to/from Kaneohe Bay Drive. Busses arrive with a headway[4] of between 15 and 30 minutes for either direction. It is therefore recommended that Oahu Transit Services (OTS) and the school bus operator for Puohala Elementary School be contacted to inform them of the planned routing of heavy vehicles.

School Pedestrian Traffic

No sidewalks are provided along Puohala Street or Kulauli Street. Therefore, in order to ensure the maximum possible safety for school children that walk to and from Puohala Elementary School and Castle High School along Kulauli Street and Puohala Street, it is recommended that construction-related heavy vehicles avoid traversing the proposed route between 15 minutes before the end of and 30 minutes after the end of the school day during times of the year when school is in-session. Puohala Elementary School's hours are between 7:45 AM and 2:05 PM on Monday, Tuesday, Thursday, and Friday; on Wednesday the hours are between 7:45 AM and 12:35 PM. Castle High School's hours are shown in Table 1 below:

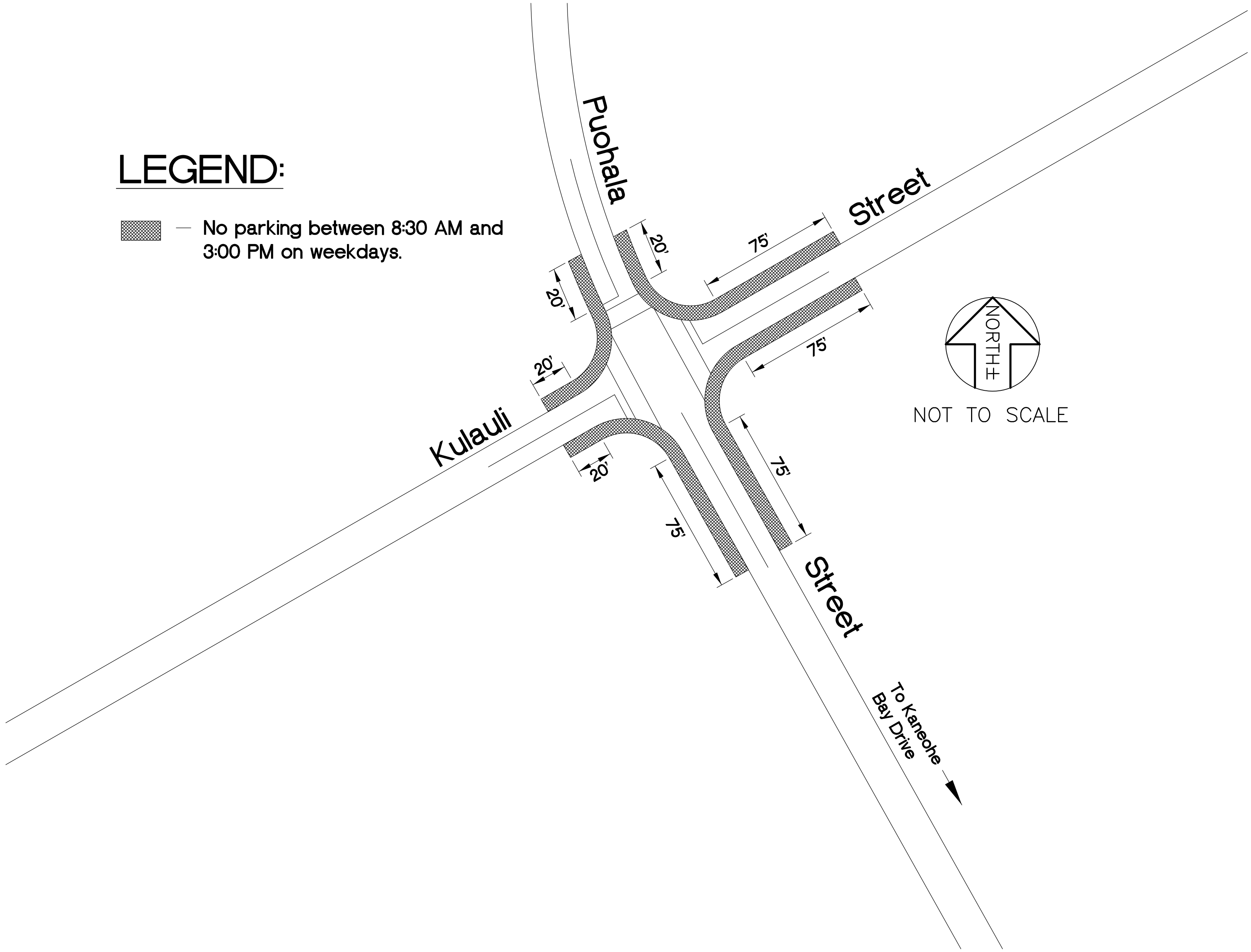
[4] Time between successive busses.

Table 1: Castle High School Schedule

Day	***Start***	***Finish***
Monday	7:50 AM	2:28 PM
Tuesday	7:50 AM	2:33 PM
Wednesday	7:50 AM	1:07 PM
Thursday	7:50 AM	2:33 PM
Friday	7:50 AM	1:43 PM

Parking Restrictions

In order to avoid the potential for conflict between the paths of heavy vehicles and parked cars at the Puohala Street/Kulauli Street intersection, it is recommended that parking be prohibited at the areas shown on Figure 8.



KAILUA/KANEOHE FORCE MAIN NO. 2
CITY AND COUNTY OF HONOLULU

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SOUTH SITE PARKING PROHIBITIONS FOR TRUCK TURNING

FIGURE 8

IV. CONCLUSIONS

North Site

Some queuing could occur as a result of the trenchwork necessary to install the sewer line under Kaneohe Bay Drive. However, based upon data taken at a similar location in Kihei, Maui, Hawaii, this queuing will not likely impact conditions on the H-3 Freeway.

The estimated six (6) heavy vehicles per hour used to transport spoils and equipment between the North and South Sites and the Waianae Landfill are not anticipated to impose any significant traffic impacts on the surrounding roadway network.

South Site

The Bayview Golf Course Route (alternate) would pose no traffic-related problems. It would, however, incur significant additional costs as a result of the following requirements:

1. The construction of a new approximately 0.3-mile segment through the existing Bayview Golf Course, which would include a stream crossing. This would necessitate the upgrading of the existing bridge or the creation of a new bridge if the existing bridge is found to be inadequate, and
2. Land acquisition or easement through Bayview Golf Course.

The Proposed Route would require construction-related heavy vehicles to traverse the residential Puohala Street and Kulauli Street – both of which are in residential neighborhoods, do not provide sidewalks, and are located near Puohala Elementary School and Castle High School. In addition, TheBus route 56 passes traverses Puohala Street in both directions.

There may be the potential for heavy vehicle conflicts at the Puohala Street/Kulauli Street intersection; this could be mitigated through:

- Parking restrictions along its corners as shown in Figure 8,
- Coordination of heavy vehicle schedules, and
- Coordination with TheBus and the school bus operator.

Given the relatively light projected volume of six (6) heavy vehicles per hour that would transport spoils and equipment outside of the peak hours of traffic, neither route is anticipated to significantly impact traffic.

V. RECOMMENDATIONS

North Site

1. Maintain as a minimum a single-lane entry and single-lane exit access to the H-3 Freeway On- and Off-Ramp; trench through right-turn and left-turn entering/exiting lanes separately.
2. Maintain the flow of traffic along Kaneohe Bay Drive to a minimum of a single, police-directed, bi-directional lane.
3. Provide left-turn access into at least two (2) of the internally interconnected Aikahi Gardens access roads at all times.
4. Maintain existing TheBus access; coordinate with OTS to relocate bus stops when necessary.

South Site

1. Construction-related heavy vehicles could utilize either the Kulauli Street/Puohala Street or the Bayview Golf Course routes to access Kaneohe Bay Drive.
2. If the Kulauli Street/Puohala Street route is used for access to the South Site, it is recommended that:
    a. Heavy vehicle drivers coordinate their route schedules as to prevent entering and exiting heavy vehicles from crossing the paths of one another while on Kulauli Street or Puohala Street.
    b. Neighborhood residents, Oahu Transit Services (OTS) and the School Bus operator for Puohala Elementary School be informed of the heavy vehicle truck routes and construction hours.
    c. Heavy Vehicle traffic not traverse Puohala Street and Kulauli Street between 15 minutes before and 30 minutes after Castle High School and Puohala Elementary School are dismissed.

d. Parking be prohibited during construction hours at the Puohala Street/Kulauli Street intersection as shown in Figure 8.

VI. REFERENCES

1. Federal Highway Administration, Manual on Uniform Traffic Control Devices for Streets and Highways, 2009.

2. Transportation Research Board, Highway Capacity Manual, 2000.

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APPENDICES

APPENDIX A

TRAFFIC COUNT DATA

APPENDIX A

TRAFFIC COUNT DATA

- North Site 24-Hour Counts from DOT

State of Hawaii, Department of Transportation, Highways Division

PROCESSING DATE: 03/27/2007
ISLAND: Oahu
STATION NO: 006511001650
AUX NO:
FUND SYSTEM:
FILE NO: 0065110016502V.xls
COUNTY:

FILE NAME: C:\Hawaii\0065110016502V.xls
STATION DESCRIPTION: Kaneohe Bay Dr. B/T H-3 & Molo
ID NO: 120651100101

COUNT GROUP ID:
ROUTE NO: 6511
HWY ST NAME: Kaneohe Bay Dr.
DIR 1: SB To Mokapu Rd.
DIR 2: SB To Mokapu Saddle Road

M.P.:

CORRIDOR ID:
SURVEY DATE: 2/9/2007

ASSIGNED DATE: 2/8/2007

BEGIN SURVEY DATE: 2/8/2007
END SURVEY DATE: 2/9/2007

START TIME: 00:00
END TIME: 24:00

Conducted by:
The Traffic Group, Inc.
www.trafficgroup.com
1-800-583-8411

TIME-AM	DIR 1	DIR 2	TOTAL	TIME-AM	DIR 1	DIR 2	TOTAL	TIME-PM	DIR 1	DIR 2	TOTAL	TIME-PM	DIR 1	DIR 2	TOTAL
12:00-12:15	10	6	16	6:00-6:15	12	65	77	12:00-12:15	67	73	140	6:00-6:15	63	72	135
12:15-12:30	10	7	17	6:15-6:30	24	81	105	12:15-12:30	48	52	100	6:15-6:30	75	54	129
12:30-12:45	8	10	18	6:30-6:45	25	85	110	12:30-12:45	42	62	104	6:30-6:45	73	54	127
12:45-1:00	5	5	10	6:45-7:00	48	119	167	12:45-1:00	50	68	118	6:45-7:00	70	54	124
1:00-1:15	8	6	14	7:00-7:15	57	118	175	1:00-1:15	52	65	117	7:00-7:15	53	43	96
1:15-1:30	5	3	8	7:15-7:30	60	115	175	1:15-1:30	60	48	108	7:15-7:30	44	40	84
1:30-1:45	6	6	12	7:30-7:45	103	119	222	1:30-1:45	59	58	117	7:30-7:45	43	36	79
1:45-2:00	8	4	12	7:45-8:00	77	130	207	1:45-2:00	61	50	111	7:45-8:00	41	39	80
2:00-2:15	4	2	6	8:00-8:15	61	90	151	2:00-2:15	62	47	109	8:00-8:15	31	52	83
2:15-2:30	4	2	6	8:15-8:30	57	87	144	2:15-2:30	77	85	162	8:15-8:30	36	47	83
2:30-2:45	3	2	5	8:30-8:45	51	75	126	2:30-2:45	70	75	145	8:30-8:45	30	26	56
2:45-3:00	4	4	8	8:45-9:00	48	54	102	2:45-3:00	65	55	120	8:45-9:00	27	34	61
3:00-3:15	1	5	6	9:00-9:15	41	64	105	3:00-3:15	66	61	127	9:00-9:15	25	30	55
3:15-3:30	4	4	8	9:15-9:30	37	48	85	3:15-3:30	74	80	154	9:15-9:30	41	35	76
3:30-3:45	2	7	9	9:30-9:45	34	65	99	3:30-3:45	101	62	163	9:30-9:45	38	27	65
3:45-4:00	2	11	13	9:45-10:00	48	68	116	3:45-4:00	78	75	153	9:45-10:00	36	27	63
4:00-4:15	3	2	5	10:00-10:15	44	57	101	4:00-4:15	103	74	177	10:00-10:15	34	48	82
4:15-4:30	3	13	16	10:15-10:30	31	68	99	4:15-4:30	92	72	164	10:15-10:30	29	38	67
4:30-4:45	4	12	16	10:30-10:45	54	54	108	4:30-4:45	109	63	172	10:30-10:45	32	29	61
4:45-5:00	3	32	35	10:45-11:00	40	72	112	4:45-5:00	116	82	198	10:45-11:00	33	26	59
5:00-5:15	7	30	37	11:00-11:15	57	65	122	5:00-5:15	98	79	177	11:00-11:15	22	20	42
5:15-5:30	6	53	59	11:15-11:30	46	57	103	5:15-5:30	89	76	165	11:15-11:30	20	15	35
5:30-5:45	15	41	56	11:30-11:45	45	77	122	5:30-5:45	73	75	148	11:30-11:45	22	14	36
5:45-6:00	17	32	49	11:45-12:00	62	58	120	5:45-6:00	87	74	161	11:45-12:00	13	17	30

AM COMMUTER PERIOD (05:00-09:00)	DIR 1	DIR 2		TOTAL
TWO DIRECTIONAL PEAK				
AM - PEAK HR TIME	-------	-------	7:00 AM-8:00 AM	
AM - PEAK HR VOLUME	297	482		779
AM - K FACTOR				8.94
AM - D%	38.13	61.87		100.00
DIRECTIONAL PEAK				
AM - PEAK HR TIME	7:15 AM-8:15 AM	7:00 AM-8:00 AM		
AM - PEAK HR VOLUME	301	482		
AM PERIOD (00:00-12:00)				
TWO DIRECTIONAL PEAK				
AM - PEAK HR TIME	-------	-------	7:00 AM-8:00 AM	
AM - PEAK HR VOLUME	297	482		779
AM - K FACTOR				8.94
AM - D%	38.13	61.87		100.00
NON-COMMUTER PERIOD (09:00-15:00)				
TWO DIRECTIONAL PEAK				
PEAK HR TIME	-------	-------	2:00 PM-3:00 PM	
PEAK HR VOLUME	274	262		536
DIRECTIONAL PEAK				
PEAK HR TIME	2:00 PM-3:00 PM	10:45 AM-11:45 AM		
PEAK HR VOLUME	274	271		

PM COMMUTER PERIOD (15:00-19:00)	DIR 1	DIR 2		TOTAL
TWO DIRECTIONAL PEAK				
PM - PEAK HR TIME	-------	-------	4:30 PM-5:30 PM	
PM - PEAK HR VOLUME	412	300		712
PM - K FACTOR				8.17
PM - D%	57.87	42.13		100.00
DIRECTIONAL PEAK				
PM - PEAK HR TIME	4:00 PM-5:00 PM	4:45 PM-5:45 PM		
PM - PEAK HR VOLUME	420	312		
PM PERIOD (00:00-12:00)				
TWO DIRECTIONAL PEAK				
PM - PEAK HR TIME	-------	-------	4:30 PM-5:30 PM	
PM - PEAK HR VOLUME	412	300		712
PM - K FACTOR				8.17
PM - D%	57.87	42.13		100.00
6-HR, 12-HR, 24-HR PERIODS				
AM 6-HR PERIOD (06:00-12:00)	1,162	1,891		3,053
AM 12-HR PERIOD (00:00-12:00)	1,304	2,190		3,494
PM 6-HR PERIOD (12:00-18:00)	1,799	1,611		3,410
PM 12-HR PERIOD (12:00-24:00)	2,730	2,488		5,218
24 HOUR PERIOD	4,034	4,678		8,712
D%	46.30	53.70		100.00

APPENDIX A

TRAFFIC COUNT DATA

- North Site Peak Hour Turning Movement Counts

Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

H3 Ramps
AM Peak Hour

File Name : Kaneohe Bay - H3 Ramps AM
Site Code : 00000000
Start Date : 10/28/2009

Groups Printed- Unshifted

	H3 Off Ramp From North				Kaneohe Bay From East				From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
06:30	3	0	24	0	49	69	0	0	0	0	0	0	0	27	45	0	217
06:45	1	0	19	0	44	66	0	0	0	0	0	0	0	26	44	0	200
Total	4	0	43	0	93	135	0	0	0	0	0	0	0	53	89	0	417
07:00	6	0	13	0	43	80	0	0	0	0	0	0	0	47	50	0	239
07:15	1	0	23	0	54	82	0	0	0	0	0	0	0	68	53	0	281
07:30	0	0	19	0	50	102	0	0	0	0	0	0	0	96	41	0	308
07:45	5	0	24	0	45	111	0	0	0	0	0	0	0	60	27	0	272
Total	12	0	79	0	192	375	0	0	0	0	0	0	0	271	171	0	1100
08:00	3	0	20	0	25	83	0	0	0	0	0	0	0	44	14	0	189
08:15	4	0	16	0	28	58	0	0	0	0	0	0	0	33	22	0	161
Grand Total	23	0	158	0	338	651	0	0	0	0	0	0	0	401	296	0	1867
Apprch %	12.7	0	87.3	0	34.2	65.8	0	0	0	0	0	0	0	57.5	42.5	0	
Total %	1.2	0	8.5	0	18.1	34.9	0	0	0	0	0	0	0	21.5	15.9	0	

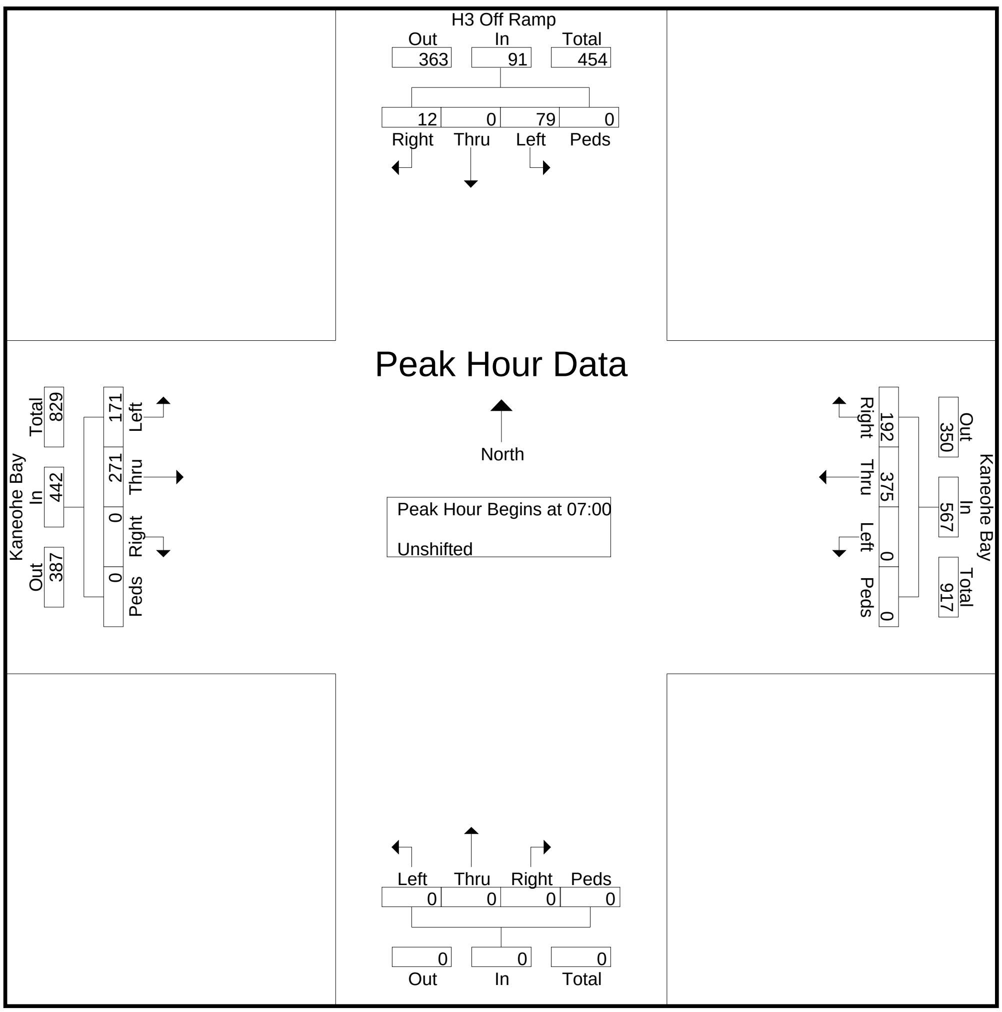
Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

H3 Ramps
AM Peak Hour

File Name : Kaneohe Bay - H3 Ramps AM
Site Code : 00000000
Start Date : 10/28/2009
Page No : 2

	H3 Off Ramp From North					Kaneohe Bay From East					From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 06:30 to 08:15 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 07:00																					
07:00	**6**	0	13	0	19	43	80	0	0	123	0	0	0	0	0	0	47	50	0	97	239
07:15	1	0	23	0	24	**54**	82	0	0	136	0	0	0	0	0	0	68	**53**	0	121	281
07:30	0	0	19	0	19	50	102	0	0	152	0	0	0	0	0	0	**96**	41	0	**137**	**308**
07:45	5	0	**24**	0	**29**	45	**111**	0	0	**156**	0	0	0	0	0	0	60	27	0	87	272
Total Volume	12	0	79	0	91	192	375	0	0	567	0	0	0	0	0	0	271	171	0	442	1100
% App. Total	13.2	0	86.8	0		33.9	66.1	0	0		0	0	0	0		0	61.3	38.7	0		
PHF	.500	.000	.823	.000	.784	.889	.845	.000	.000	.909	.000	.000	.000	.000	.000	.000	.706	.807	.000	.807	.893



Austin, Tsutsumi and Associates
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

Molo
AM Peak Hour

File Name : Kaneohe Bay - Molo AM
Site Code : 00000000
Start Date : 10/28/2009

Groups Printed- Unshifted - Bank 1

	Molo From North				Kaneohe Bay From East				Molo From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
06:30	0	0	0	0	0	107	0	0	4	0	6	1	0	50	0	0	168
06:45	0	0	0	0	0	111	0	0	4	0	3	1	1	44	0	0	164
Total	0	0	0	0	0	218	0	0	8	0	9	2	1	94	0	0	332
07:00	0	0	0	0	0	113	1	0	2	0	3	0	0	58	0	0	177
07:15	0	0	0	0	0	135	2	0	1	0	5	1	0	88	0	0	232
07:30	0	0	0	0	0	144	1	0	5	0	2	0	1	107	0	0	260
07:45	0	0	0	0	0	151	1	0	2	0	3	0	0	88	0	0	245
Total	0	0	0	0	0	543	5	0	10	0	13	1	1	341	0	0	914
08:00	0	0	0	0	0	107	2	0	2	0	3	1	3	62	0	0	180
08:15	0	0	0	0	0	85	0	0	3	0	0	2	0	51	0	0	141
Grand Total	0	0	0	0	0	953	7	0	23	0	25	6	5	548	0	0	1567
Apprch %	0	0	0	0	0	99.3	0.7	0	42.6	0	46.3	11.1	0.9	99.1	0	0	
Total %	0	0	0	0	0	60.8	0.4	0	1.5	0	1.6	0.4	0.3	35	0	0	
Unshifted	0	0	0	0	0	953	7	0	23	0	25	6	5	548	0	0	1567
% Unshifted	0	0	0	0	0	100	100	0	100	0	100	100	100	100	0	0	100
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

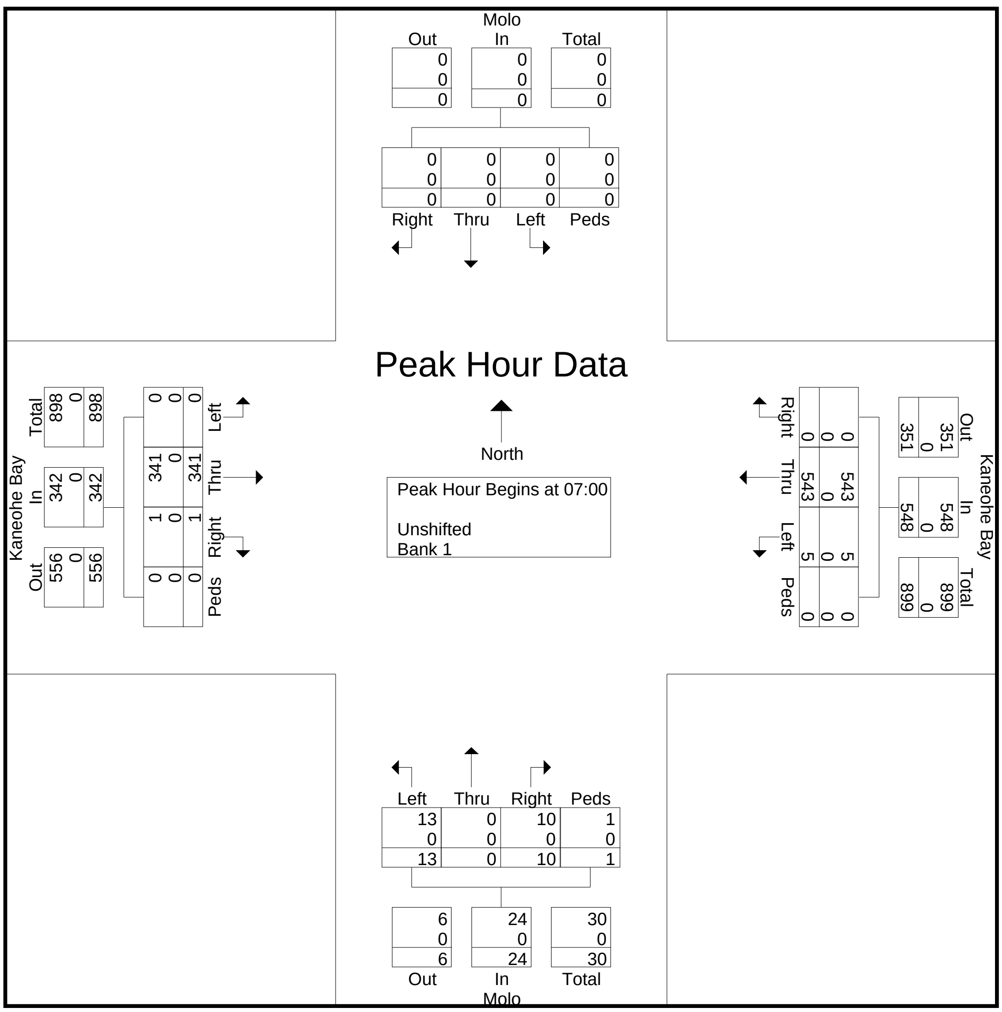
Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

Molo
AM Peak Hour

File Name : Kaneohe Bay - Molo AM
Site Code : 00000000
Start Date : 10/28/2009
Page No : 2

	Molo From North					Kaneohe Bay From East					Molo From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 07:00 to 07:45 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 07:00																					
07:00	0	0	0	0	0	0	113	1	0	114	2	0	3	0	5	0	58	0	0	58	177
07:15	0	0	0	0	0	0	135	**2**	0	137	1	0	**5**	**1**	**7**	0	88	0	0	88	232
07:30	0	0	0	0	0	0	144	1	0	145	**5**	0	2	0	7	**1**	**107**	0	0	**108**	**260**
07:45	0	0	0	0	0	0	**151**	1	0	**152**	2	0	3	0	5	0	88	0	0	88	245
Total Volume	0	0	0	0	0	0	543	5	0	548	10	0	13	1	24	1	341	0	0	342	914
% App. Total	0	0	0	0		0	99.1	0.9	0		41.7	0	54.2	4.2		0.3	99.7	0	0		
PHF	.000	.000	.000	.000	.000	.000	.899	.625	.000	.901	.500	.000	.650	.250	.857	.250	.797	.000	.000	.792	.879
Unshifted	0	0	0	0	0	0	543	5	0	548	10	0	13	1	24	1	341	0	0	342	914
% Unshifted																					
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

Lale
AM Peak Hour

File Name : Kaneohe Bay - Lale AM
Site Code : 00000000
Start Date : 10/28/2009

Groups Printed- Unshifted - Bank 1

	Lale From North				Kaneohe Bay From East				Lale From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
06:30	0	0	0	0	0	109	3	0	3	0	2	1	0	55	0	0	173
06:45	0	0	0	0	0	106	0	0	2	0	3	0	0	48	0	0	159
Total	0	0	0	0	0	215	3	0	5	0	5	1	0	103	0	0	332
07:00	0	0	0	0	0	125	2	0	4	0	2	0	1	62	0	0	196
07:15	0	0	0	0	0	136	3	0	5	0	4	1	0	89	0	0	238
07:30	0	0	0	0	0	149	3	0	11	0	1	0	2	112	0	0	278
07:45	0	0	0	0	0	156	3	0	1	0	0	0	1	89	0	0	250
Total	0	0	0	0	0	566	11	0	21	0	7	1	4	352	0	0	962
08:00	0	0	0	0	0	108	1	0	3	0	0	1	0	63	0	0	176
08:15	0	0	0	0	0	83	1	0	1	0	2	1	0	53	0	0	141
Grand Total	0	0	0	0	0	972	16	0	30	0	14	4	4	571	0	0	1611
Apprch %	0	0	0	0	0	98.4	1.6	0	62.5	0	29.2	8.3	0.7	99.3	0	0	
Total %	0	0	0	0	0	60.3	1	0	1.9	0	0.9	0.2	0.2	35.4	0	0	
Unshifted	0	0	0	0	0	972	16	0	30	0	14	4	4	571	0	0	1611
% Unshifted	0	0	0	0	0	100	100	0	100	0	100	100	100	100	0	0	100
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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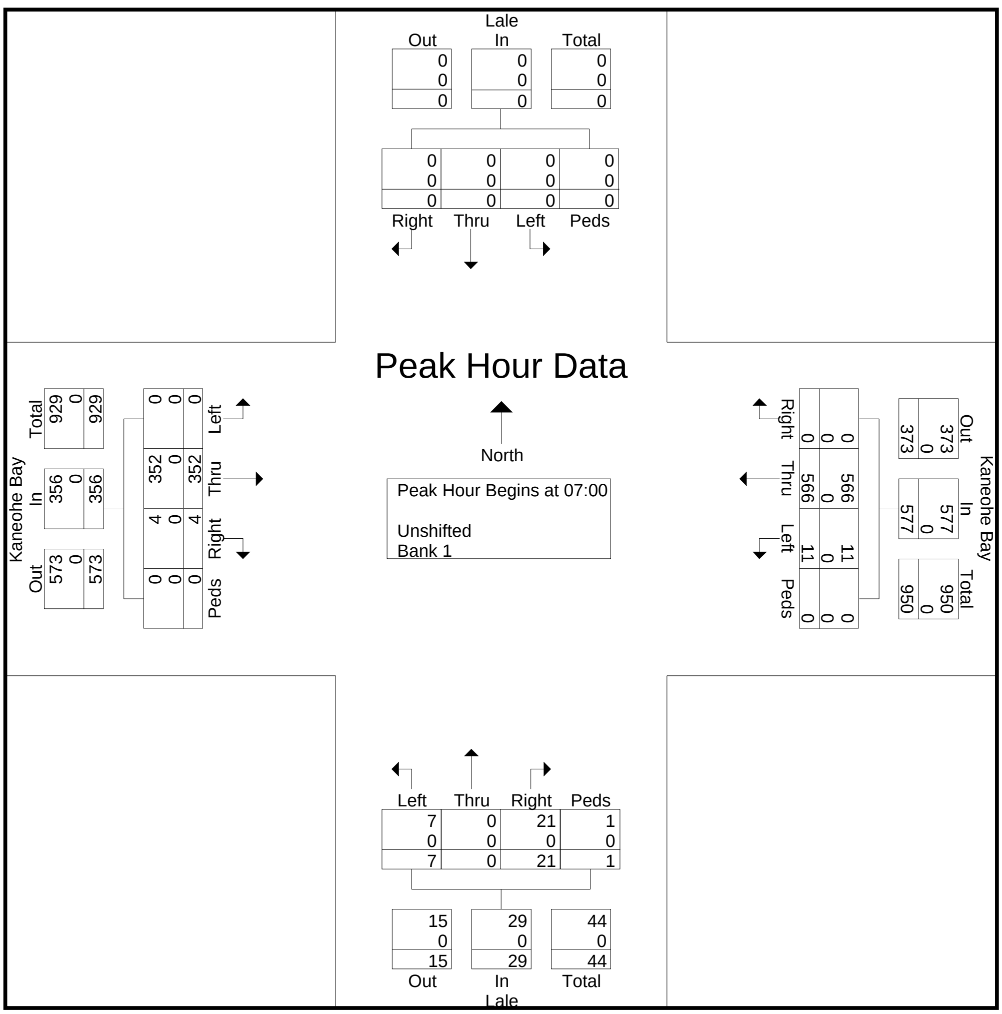
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

Lale
AM Peak Hour

File Name : Kaneohe Bay - Lale AM
Site Code : 00000000
Start Date : 10/28/2009
Page No : 2

	Lale From North					Kaneohe Bay From East					Lale From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 06:30 to 08:15 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 07:00																					
07:00	0	0	0	0	0	0	125	2	0	127	4	0	2	0	6	1	62	0	0	63	196
07:15	0	0	0	0	0	0	136	**3**	0	139	5	0	**4**	**1**	10	0	89	0	0	89	238
07:30	0	0	0	0	0	0	149	3	0	152	**11**	0	1	0	**12**	**2**	**112**	0	0	**114**	**278**
07:45	0	0	0	0	0	0	**156**	3	0	**159**	1	0	0	0	1	1	89	0	0	90	250
Total Volume	0	0	0	0	0	0	566	11	0	577	21	0	7	1	29	4	352	0	0	356	962
% App. Total	0	0	0	0		0	98.1	1.9	0		72.4	0	24.1	3.4		1.1	98.9	0	0		
PHF	.000	.000	.000	.000	.000	.000	.907	.917	.000	.907	.477	.000	.438	.250	.604	.500	.786	.000	.000	.781	.865
Unshifted	0	0	0	0	0	0	566	11	0	577	21	0	7	1	29	4	352	0	0	356	962
% Unshifted																					
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



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Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

H3 Ramps
PM Peak Hour

File Name : Kaneohe Bay - H3 Ramps PM
Site Code : 00000000
Start Date : 10/28/2009
Page No : 1

Groups Printed- Unshifted - Bank 1

	H3 Ramps From North				Kaneohe Bay From East				H3 From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
15:30	3	0	22	0	18	86	0	0	0	0	0	0	0	74	15	0	218
15:45	10	0	40	0	17	70	0	0	0	0	0	0	0	70	13	0	220
Total	13	0	62	0	35	156	0	0	0	0	0	0	0	144	28	0	438
16:00	9	0	42	0	23	77	0	0	0	0	0	0	0	64	19	0	234
16:15	5	0	32	0	28	69	0	0	0	0	0	0	0	78	29	0	241
16:30	14	0	54	0	7	86	0	0	0	0	0	0	0	92	22	0	275
16:45	7	0	59	0	33	63	0	0	0	0	0	0	0	78	22	0	262
Total	35	0	187	0	91	295	0	0	0	0	0	0	0	312	92	0	1012
17:00	17	0	35	0	19	86	0	0	0	0	0	0	0	66	22	0	245
17:15	8	0	40	0	19	67	0	0	0	0	0	0	0	70	15	0	219
17:30	13	0	37	0	28	53	0	0	0	0	0	0	0	55	19	0	205
17:45	10	0	25	0	19	59	0	0	0	0	0	0	0	64	19	0	196
Total	48	0	137	0	85	265	0	0	0	0	0	0	0	255	75	0	865
Grand Total	96	0	386	0	211	716	0	0	0	0	0	0	0	711	195	0	2315
Apprch %	19.9	0	80.1	0	22.8	77.2	0	0	0	0	0	0	0	78.5	21.5	0	
Total %	4.1	0	16.7	0	9.1	30.9	0	0	0	0	0	0	0	30.7	8.4	0	
Unshifted	96	0	386	0	211	716	0	0	0	0	0	0	0	711	195	0	2315
% Unshifted	100	0	100	0	100	100	0	0	0	0	0	0	0	100	100	0	100
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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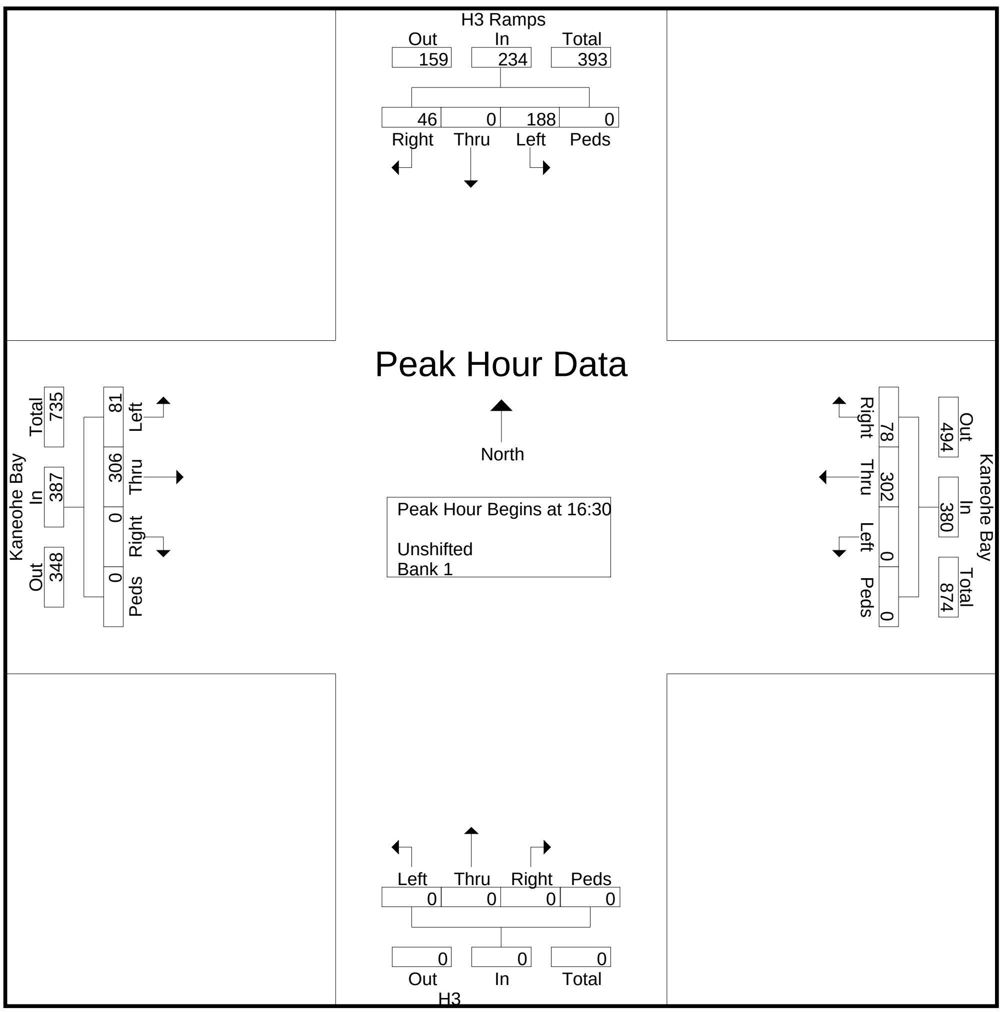
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

H3 Ramps
PM Peak Hour

File Name : Kaneohe Bay - H3 Ramps PM
Site Code : 00000000
Start Date : 10/28/2009

	H3 Ramps From North					Kaneohe Bay From East					H3 From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 16:30 to 17:15 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 16:30																					
16:30	14	0	54	0	**68**	7	**86**	0	0	93	0	0	0	0	0	0	**92**	**22**	0	**114**	**275**
16:45	7	0	**59**	0	66	**33**	63	0	0	96	0	0	0	0	0	0	78	22	0	100	262
17:00	**17**	0	35	0	52	19	86	0	0	**105**	0	0	0	0	0	0	66	22	0	88	245
17:15	8	0	40	0	48	19	67	0	0	86	0	0	0	0	0	0	70	15	0	85	219
Total Volume	46	0	188	0	234	78	302	0	0	380	0	0	0	0	0	0	306	81	0	387	1001
% App. Total	19.7	0	80.3	0		20.5	79.5	0	0		0	0	0	0		0	79.1	20.9	0		
PHF	.676	.000	.797	.000	.860	.591	.878	.000	.000	.905	.000	.000	.000	.000	.000	.000	.832	.920	.000	.849	.910



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501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

Molo
PM Peak Hour

File Name : Kaneohe Bay - Molo PM
Site Code : 00000000
Start Date : 10/28/2009

Groups Printed- Unshifted - Bank 1

	Molo From North				Kaneohe Bay From East				Molo From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
15:30	0	0	0	0	0	103	4	0	2	0	2	0	6	92	0	0	209
15:45	0	0	0	0	0	82	3	0	5	0	3	1	4	104	0	0	202
Total	0	0	0	0	0	185	7	0	7	0	5	1	10	196	0	0	411
16:00	0	0	0	0	0	91	1	0	0	0	1	0	1	98	0	0	192
16:15	0	0	0	0	0	96	2	0	1	0	1	5	3	102	0	0	210
16:30	0	0	0	0	0	89	3	0	0	0	2	0	9	131	0	0	234
16:45	0	0	0	0	0	97	1	0	2	0	1	0	4	143	0	0	248
Total	0	0	0	0	0	373	7	0	3	0	5	5	17	474	0	0	884
17:00	0	0	0	0	0	100	2	0	1	0	2	2	1	101	0	0	209
17:15	0	0	0	0	0	84	3	0	1	0	2	4	2	111	0	0	207
17:30	0	0	0	0	0	74	1	0	1	0	2	2	2	90	0	0	172
17:45	0	0	0	0	0	83	0	0	3	0	0	1	1	85	0	0	173
Total	0	0	0	0	0	341	6	0	6	0	6	9	6	387	0	0	761
Grand Total	0	0	0	0	0	899	20	0	16	0	16	15	33	1057	0	0	2056
Apprch %	0	0	0	0	0	97.8	2.2	0	34	0	34	31.9	3	97	0	0	
Total %	0	0	0	0	0	43.7	1	0	0.8	0	0.8	0.7	1.6	51.4	0	0	
Unshifted	0	0	0	0	0	899	20	0	16	0	16	15	33	1057	0	0	2056
% Unshifted	0	0	0	0	0	100	100	0	100	0	100	100	100	100	0	0	100
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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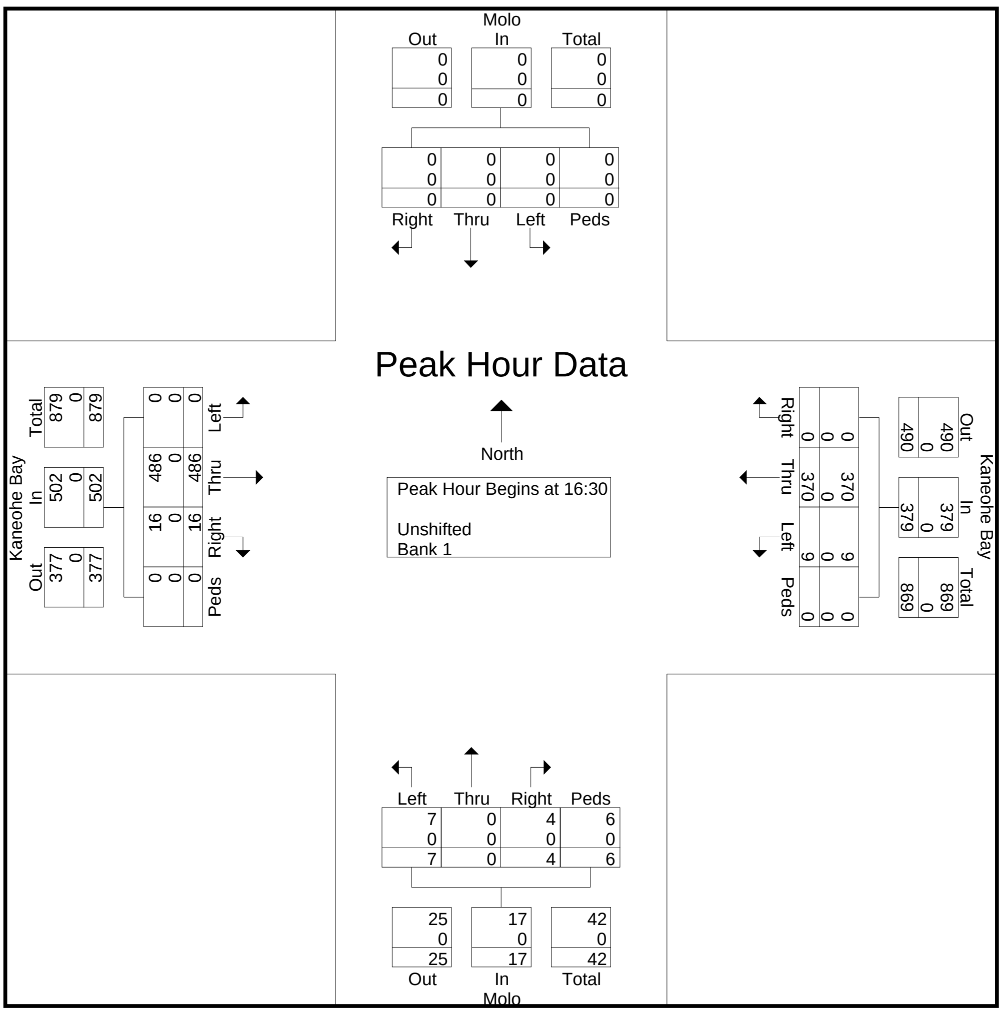
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

Molo
PM Peak Hour

File Name : Kaneohe Bay - Molo PM
Site Code : 00000000
Start Date : 10/28/2009
Page No : 2

	Molo From North					Kaneohe Bay From East					Molo From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 16:30 to 17:15 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 16:30																					
16:30	0	0	0	0	0	0	89	**3**	0	92	0	0	**2**	0	2	**9**	131	0	0	140	234
16:45	0	0	0	0	0	0	97	1	0	98	**2**	0	1	0	3	4	**143**	0	0	**147**	**248**
17:00	0	0	0	0	0	0	**100**	2	0	**102**	1	0	2	2	5	1	101	0	0	102	209
17:15	0	0	0	0	0	0	84	3	0	87	1	0	2	**4**	**7**	2	111	0	0	113	207
Total Volume	0	0	0	0	0	0	370	9	0	379	4	0	7	6	17	16	486	0	0	502	898
% App. Total	0	0	0	0		0	97.6	2.4	0		23.5	0	41.2	35.3		3.2	96.8	0	0		
PHF	.000	.000	.000	.000	.000	.000	.925	.750	.000	.929	.500	.000	.875	.375	.607	.444	.850	.000	.000	.854	.905
Unshifted	0	0	0	0	0	0	370	9	0	379	4	0	7	6	17	16	486	0	0	502	898
% Unshifted																					
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



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501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

Lale
PM Peak Hour

File Name : Kaneohe Bay - Lale PM
Site Code : 00000000
Start Date : 10/28/2009
Page No : 1

Groups Printed- Unshifted - Bank 1

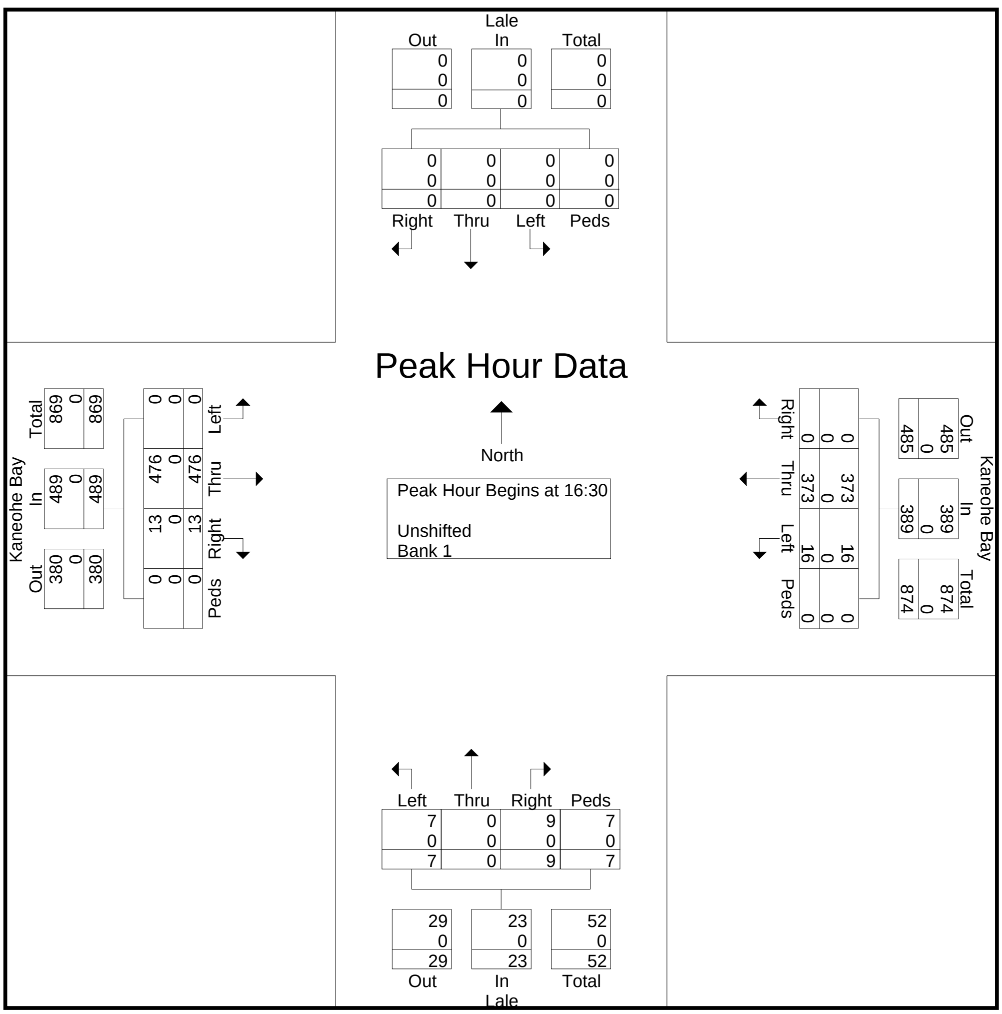
	Lale From North				Kaneohe Bay From East				Lale From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
15:30	0	0	0	0	0	111	3	0	8	0	2	0	2	100	0	0	226
15:45	0	0	0	0	0	85	1	0	2	0	3	1	2	106	0	0	200
Total	0	0	0	0	0	196	4	0	10	0	5	1	4	206	0	0	426
16:00	0	0	0	0	0	95	0	0	1	0	1	2	2	95	0	0	196
16:15	0	0	0	0	0	96	3	0	5	0	2	3	2	100	0	0	211
16:30	0	0	0	0	0	91	2	0	1	0	4	3	3	136	0	0	240
16:45	0	0	0	0	0	97	4	0	3	0	1	1	4	138	0	0	248
Total	0	0	0	0	0	379	9	0	10	0	8	9	11	469	0	0	895
17:00	0	0	0	0	0	99	3	0	3	0	2	0	3	91	0	0	201
17:15	0	0	0	0	0	86	7	0	2	0	0	3	3	111	0	0	212
17:30	0	0	0	0	0	77	4	0	3	0	1	3	2	92	0	0	182
17:45	0	0	0	0	0	83	5	0	2	0	1	0	1	85	0	0	177
Total	0	0	0	0	0	345	19	0	10	0	4	6	9	379	0	0	772
Grand Total	0	0	0	0	0	920	32	0	30	0	17	16	24	1054	0	0	2093
Apprch %	0	0	0	0	0	96.6	3.4	0	47.6	0	27	25.4	2.2	97.8	0	0	
Total %	0	0	0	0	0	44	1.5	0	1.4	0	0.8	0.8	1.1	50.4	0	0	
Unshifted	0	0	0	0	0	920	32	0	30	0	17	16	24	1054	0	0	2093
% Unshifted	0	0	0	0	0	100	100	0	100	0	100	100	100	100	0	0	100
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Austin, Tsutsumi and Associates
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

Lale
PM Peak Hour

File Name : Kaneohe Bay - Lale PM
Site Code : 00000000
Start Date : 10/28/2009

	Lale From North					Kaneohe Bay From East					Lale From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 15:30 to 17:45 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 16:30																					
16:30	0	0	0	0	0	0	91	2	0	93	1	0	**4**	**3**	**8**	3	136	0	0	139	240
16:45	0	0	0	0	0	0	97	4	0	101	**3**	0	1	1	5	**4**	**138**	0	0	**142**	**248**
17:00	0	0	0	0	0	0	**99**	3	0	**102**	3	0	2	0	5	3	91	0	0	94	201
17:15	0	0	0	0	0	0	86	**7**	0	93	2	0	0	3	5	3	111	0	0	114	212
Total Volume	0	0	0	0	0	0	373	16	0	389	9	0	7	7	23	13	476	0	0	489	901
% App. Total	0	0	0	0		0	95.9	4.1	0		39.1	0	30.4	30.4		2.7	97.3	0	0		
PHF	.000	.000	.000	.000	.000	.000	.942	.571	.000	.953	.750	.000	.438	.583	.719	.813	.862	.000	.000	.861	.908
Unshifted	0	0	0	0	0	0	373	16	0	389	9	0	7	7	23	13	476	0	0	489	901
% Unshifted																					
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



APPENDIX A

TRAFFIC COUNT DATA

- South Site 24-hour Counts from DOT

Run Date: 2008/06/04

Hawaii Department of Transportation

Highways Division — Highways Planning Survey Section

2007 Program Count - Summary

Site ID: B72006500040
Functional Class: URBAN:PRINCIPAL ARTERIAL - OTHER
Location: KANEOHE BAY DR - PUOHALA ST. / BEG. OF 2

Town: Oahu
Count Type: VOLUME
Counter Type: Tube

Final AADT: 0
Route No: 65
DIR 1: +MP **DIR 2:** -MP

DATE : 06/06/2007

TIME-AM	DIR 1	DIR 2	TOTAL	TIME-AM	DIR 1	DIR 2	TOTAL	TIME-PM	DIR 1	DIR 2	TOTAL	TIME-PM	DIR 1	DIR 2	TOTAL
12:00-12:15	26	29	55	06:00-06:15	77	111	188	12:00-12:15	185	168	353	06:00-06:15	220	368	588
12:15-12:30	11	26	37	06:15-06:30	108	108	216	12:15-12:30	171	189	360	06:15-06:30	200	333	533
12:30-12:45	9	15	24	06:30-06:45	125	147	272	12:30-12:45	193	190	383	06:30-06:45	230	246	476
12:45-01:00	11	14	25	06:45-07:00	195	189	384	12:45-01:00	177	192	369	06:45-07:00	181	231	412
01:00-01:15	15	19	34	07:00-07:15	202	203	405	01:00-01:15	184	185	369	07:00-07:15	181	213	394
01:15-01:30	24	16	40	07:15-07:30	241	263	504	01:15-01:30	174	172	346	07:15-07:30	187	194	381
01:30-01:45	15	12	27	07:30-07:45	264	300	564	01:30-01:45	237	175	412	07:30-07:45	170	208	378
01:45-02:00	10	11	21	07:45-08:00	274	380	654	01:45-02:00	213	248	461	07:45-08:00	138	183	321
02:00-02:15	8	10	18	08:00-08:15	262	305	567	02:00-02:15	183	193	376	08:00-08:15	134	186	320
02:15-02:30	11	14	25	08:15-08:30	165	265	430	02:15-02:30	149	165	314	08:15-08:30	120	138	258
02:30-02:45	6	14	20	08:30-08:45	172	191	363	02:30-02:45	178	201	379	08:30-08:45	118	145	263
02:45-03:00	5	9	14	08:45-09:00	176	139	315	02:45-03:00	186	200	386	08:45-09:00	120	171	291
03:00-03:15	3	9	12	09:00-09:15	155	159	314	03:00-03:15	170	172	342	09:00-09:15	110	108	218
03:15-03:30	4	7	11	09:15-09:30	131	167	298	03:15-03:30	212	251	463	09:15-09:30	99	117	216
03:30-03:45	12	10	22	09:30-09:45	164	163	327	03:30-03:45	197	209	406	09:30-09:45	89	151	240
03:45-04:00	17	9	26	09:45-10:00	140	203	343	03:45-04:00	229	323	552	09:45-10:00	94	103	197
04:00-04:15	4	14	18	10:00-10:15	139	194	333	04:00-04:15	228	256	484	10:00-10:15	81	102	183
04:15-04:30	6	21	27	10:15-10:30	152	185	337	04:15-04:30	226	252	478	10:15-10:30	72	69	141
04:30-04:45	18	19	37	10:30-10:45	157	187	344	04:30-04:45	234	274	508	10:30-10:45	60	48	108
04:45-05:00	29	32	61	10:45-11:00	172	190	362	04:45-05:00	246	331	577	10:45-11:00	61	54	115
05:00-05:15	40	43	83	11:00-11:15	168	205	373	05:00-05:15	228	375	603	11:00-11:15	42	48	90
05:15-05:30	32	51	83	11:15-11:30	192	215	407	05:15-05:30	214	343	557	11:15-11:30	30	49	79
05:30-05:45	52	81	133	11:30-11:45	191	184	375	05:30-05:45	205	461	666	11:30-11:45	35	33	68
05:45-06:00	75	95	170	11:45-12:00	190	175	365	05:45-06:00	243	354	597	11:45-12:00	36	36	72

AM COMMUTER PERIOD (05:00-09:00)	DIR 1	DIR 2	
TWO DIRECTIONAL PEAK			
AM - PEAK HR TIME	07:15 AM to 08:15 AM		
AM - PEAK HR VOLUME	1041	1248	2289
AM - K FACTOR (%)			8.43
AM - D (%)	45.48	54.52	100.00
DIRECTIONAL PEAK			
AM - PEAK HR TIME	07:15 AM to 08:15 AM	07:30 AM to 08:30 AM	
AM - PEAK HR VOLUME	1041	1250	

PM COMMUTER PERIOD (15:00-19:00)	DIR 1	DIR 2	
TWO DIRECTIONAL PEAK			
PM - PEAK HR TIME	05:00 PM to 06:00 PM		
PM - PEAK HR VOLUME	890	1533	2423
PM - K FACTOR (%)			8.93
PM - D (%)	36.73	63.27	100.00
DIRECTIONAL PEAK			
PM - PEAK HR TIME	04:15 PM to 05:15 PM	05:00 PM to 06:00 PM	
PM - PEAK HR VOLUME	934	1533	

AM PERIOD (00:00-12:00)			
TWO DIRECTIONAL PEAK			
AM - PEAK HR TIME	07:15 AM to 08:15 AM		
AM - PEAK HR VOLUME	1041	1248	2289
AM - K FACTOR (%)			8.43
AM - D (%)	45.48	54.52	100.00

PM PERIOD (12:00-24:00)			
TWO DIRECTIONAL PEAK			
PM - PEAK HR TIME	05:00 PM to 06:00 PM		
PM - PEAK HR VOLUME	890	1533	2423
PM - K FACTOR (%)			8.93
PM - D (%)	36.73	63.27	100.00

NON-COMMUTER PERIOD (09:00-15:00)			
TWO DIRECTIONAL PEAK			
PEAK HR TIME	01:15 PM to 02:15 PM		
PEAK HR VOLUME	807	788	1595
DIRECTIONAL PEAK			
PEAK HR TIME	01:00 PM to 02:00 PM	01:45 PM to 02:45 PM	
PEAK HR VOLUME	808	807	

6-HR, 12-HR, 24-HR PERIODS	DIR 1	DIR 2	Total
AM 6-HR PERIOD (06:00-12:00)	4,212	4,828	9,040
AM 12-HR PERIOD (00:00-12:00)	4,655	5,408	10,063
PM 6-HR PERIOD (12:00-18:00)	4,862	5,879	10,741
PM 12-HR PERIOD (12:00-24:00)	7,670	9,413	17,083
24 HOUR PERIOD	12,325	14,821	27,146
D (%)	45.40	54.60	100.00

APPENDIX A

TRAFFIC COUNT DATA

- South Site Peak Hour Turning Movement Counts

Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

File Name : AM_Kaneohe Bay - Puohala
Site Code : 00000000
Start Date : 10/28/2009

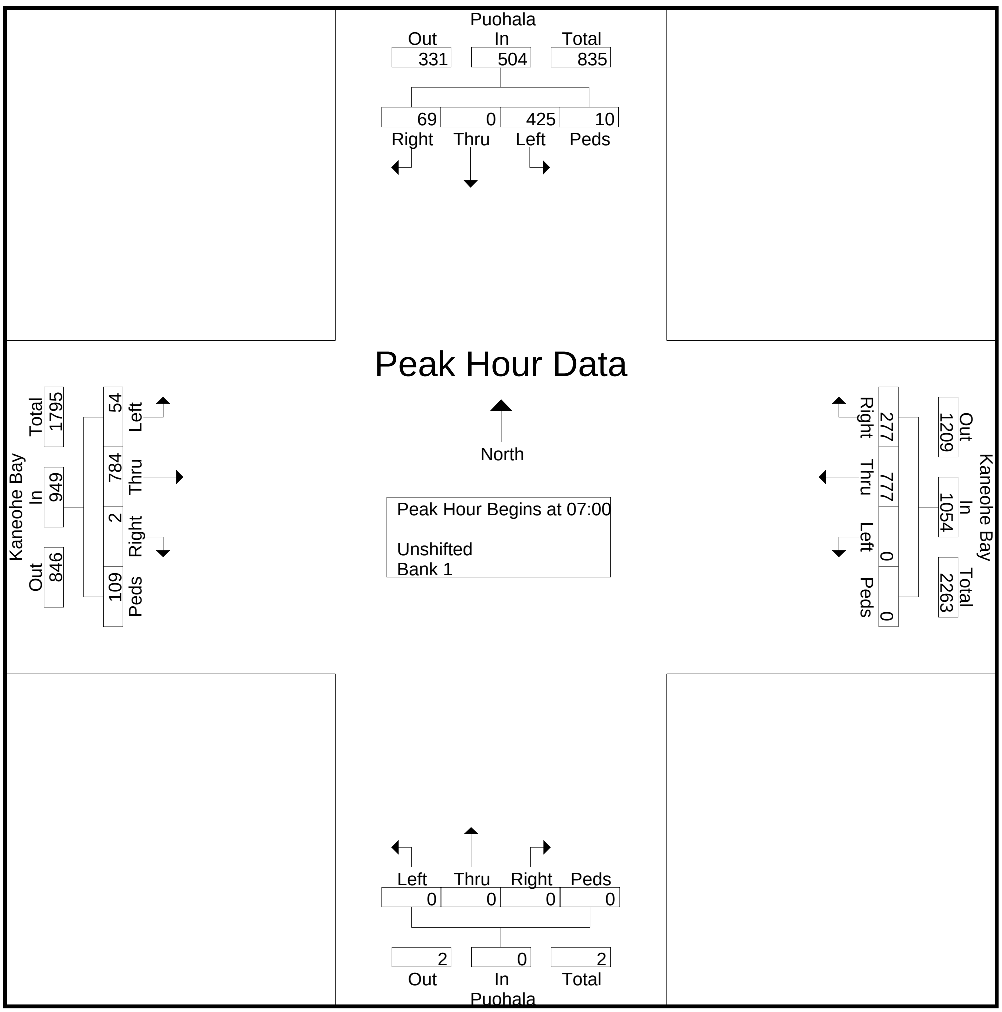
Groups Printed- Unshifted - Bank 1

	Puohala From North				Kaneohe Bay From East				Puohala From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
06:30	6	0	80	0	21	144	0	0	0	0	0	0	0	104	4	3	362
06:45	10	0	95	0	49	150	0	0	0	0	0	0	0	128	11	3	446
Total	16	0	175	0	70	294	0	0	0	0	0	0	0	232	15	6	808
07:00	13	0	121	0	31	171	0	0	0	0	0	0	0	167	10	9	522
07:15	21	0	116	5	67	182	0	0	0	0	0	0	0	164	11	15	581
07:30	21	0	99	3	82	195	0	0	0	0	0	0	2	223	18	38	681
07:45	14	0	89	2	97	229	0	0	0	0	0	0	0	230	15	47	723
Total	69	0	425	10	277	777	0	0	0	0	0	0	2	784	54	109	2507
08:00	21	0	75	0	66	186	0	0	0	0	0	0	0	112	8	4	472
08:15	11	1	57	1	37	122	0	0	0	0	0	0	0	110	6	1	346
Grand Total	117	1	732	11	450	1379	0	0	0	0	0	0	2	1238	83	120	4133
Apprch %	13.6	0.1	85	1.3	24.6	75.4	0	0	0	0	0	0	0.1	85.8	5.8	8.3	
Total %	2.8	0	17.7	0.3	10.9	33.4	0	0	0	0	0	0	0	30	2	2.9	
Unshifted	117	1	732	11	450	1379	0	0	0	0	0	0	2	1238	83	120	4133
% Unshifted	100	100	100	100	100	100	0	0	0	0	0	0	100	100	100	100	100
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

	Puohala From North					Kaneohe Bay From East					Puohala From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 07:00 to 07:45 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 07:00																					
07:00	13	0	**121**	0	134	31	171	0	0	202	0	0	0	0	0	0	167	10	9	186	522
07:15	**21**	0	116	**5**	**142**	67	182	0	0	249	0	0	0	0	0	0	164	11	15	190	581
07:30	21	0	99	3	123	82	195	0	0	277	0	0	0	0	0	**2**	223	**18**	38	281	681
07:45	14	0	89	2	105	**97**	**229**	0	0	**326**	0	0	0	0	0	0	**230**	15	**47**	**292**	**723**
Total Volume	69	0	425	10	504	277	777	0	0	1054	0	0	0	0	0	2	784	54	109	949	2507
% App. Total	13.7	0	84.3	2		26.3	73.7	0	0		0	0	0	0		0.2	82.6	5.7	11.5		
PHF	.821	.000	.878	.500	.887	.714	.848	.000	.000	.808	.000	.000	.000	.000	.000	.250	.852	.750	.580	.813	.867



Wilson Okamoto Corporation

1907 S. Beretania Street Suite 400
Honolulu, Hi 96826

Counter:D4-3891, D4-5673
Counted By:DY, JY
Weather:Clear

File Name : PuoKan Midday
Site Code : 00000001
Start Date : 11/23/2010
Page No : 1

Groups Printed- Unshifted

	Puohala Street Southbound				Kaneohe Bay Drive Westbound				Northbound	Kaneohe Bay Drive Eastbound				
Start Time	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	App. Total	Left	Thru	Right	App. Total	Int. Total
11:00 AM	64	0	15	79	0	127	58	185	0	7	110	0	117	381
11:15 AM	42	0	9	51	0	147	57	204	0	5	126	0	131	386
11:30 AM	57	0	11	68	0	116	54	170	0	5	103	0	108	346
11:45 AM	50	0	6	56	0	118	53	171	0	2	99	0	101	328
Total	213	0	41	254	0	508	222	730	0	19	438	0	457	1441
12:00 PM	57	0	5	62	0	121	49	170	0	6	104	0	110	342
12:15 PM	60	0	16	76	0	109	63	172	0	4	121	0	125	373
12:30 PM	53	0	12	65	0	113	51	164	0	5	129	0	134	363
12:45 PM	46	0	10	56	0	121	43	164	0	3	125	0	128	348
Total	216	0	43	259	0	464	206	670	0	18	479	0	497	1426
Grand Total	429	0	84	513	0	972	428	1400	0	37	917	0	954	2867
Apprch %	83.6	0	16.4		0	69.4	30.6			3.9	96.1	0		
Total %	15	0	2.9	17.9	0	33.9	14.9	48.8	0	1.3	32	0	33.3	

	Puohala Street Southbound				Kaneohe Bay Drive Westbound				Northbound	Kaneohe Bay Drive Eastbound				
Start Time	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	App. Total	Left	Thru	Right	App. Total	Int. Total
Peak Hour Analysis From 11:00 AM to 12:45 PM - Peak 1 of 1														
Peak Hour for Entire Intersection Begins at 11:00 AM														
11:00 AM	**64**	0	**15**	**79**	0	127	**58**	185	0	**7**	110	0	117	381
11:15 AM	42	0	9	51	0	**147**	57	**204**	0	5	**126**	0	**131**	**386**
11:30 AM	57	0	11	68	0	116	54	170	0	5	103	0	108	346
11:45 AM	50	0	6	56	0	118	53	171	0	2	99	0	101	328
Total Volume	213	0	41	254	0	508	222	730	0	19	438	0	457	1441
% App. Total	83.9	0	16.1		0	69.6	30.4			4.2	95.8	0		
PHF	.832	.000	.683	.804	.000	.864	.957	.895	.000	.679	.869	.000	.872	.933

Wilson Okamoto Corporation

1907 S. Beretania Street Suite 400
Honolulu, Hi 96826

Counter:D4-5676
Counted By:LKC
Weather:Clear

File Name : PuoKul Midday
Site Code : 00000001
Start Date : 11/23/2010
Page No : 1

Groups Printed- Unshifted

	Puohala Street Southbound				Kulauli Street Westbound				Puohala Street Northbound				Kulauli Street Eastbound				
Start Time	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Int. Total
11:00 AM	1	63	0	64	6	2	4	12	1	56	5	62	0	1	1	2	140
11:15 AM	2	47	0	49	2	1	3	6	0	57	2	59	1	0	2	3	117
11:30 AM	2	62	0	64	3	1	1	5	0	57	1	58	0	3	1	4	131
11:45 AM	4	48	1	53	2	2	2	6	0	51	6	57	0	2	0	2	118
Total	9	220	1	230	13	6	10	29	1	221	14	236	1	6	4	11	506
12:00 PM	2	59	3	64	8	3	4	15	0	57	10	67	0	3	0	3	149
12:15 PM	3	52	4	59	7	3	3	13	1	75	3	79	0	1	3	4	155
12:30 PM	3	56	0	59	3	2	0	5	1	40	4	45	0	1	3	4	113
12:45 PM	1	52	0	53	7	2	4	13	1	42	3	46	1	5	2	8	120
Total	9	219	7	235	25	10	11	46	3	214	20	237	1	10	8	19	537
Grand Total	18	439	8	465	38	16	21	75	4	435	34	473	2	16	12	30	1043
Apprch %	3.9	94.4	1.7		50.7	21.3	28		0.8	92	7.2		6.7	53.3	40		
Total %	1.7	42.1	0.8	44.6	3.6	1.5	2	7.2	0.4	41.7	3.3	45.3	0.2	1.5	1.2	2.9	

	Puohala Street Southbound				Kulauli Street Westbound				Puohala Street Northbound				Kulauli Street Eastbound				
Start Time	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Left	Thru	Right	App. Total	Int. Total
Peak Hour Analysis From 11:00 AM to 12:45 PM - Peak 1 of 1																	
Peak Hour for Entire Intersection Begins at 11:30 AM																	
11:30 AM	2	**62**	0	**64**	3	1	1	5	0	57	**1**	58	0	**3**	1	**4**	131
11:45 AM	**4**	48	**1**	53	2	2	2	6	0	51	6	57	0	2	0	2	118
12:00 PM	2	59	3	64	**8**	**3**	**4**	**15**	0	57	**10**	67	0	3	0	3	149
12:15 PM	3	52	**4**	59	7	3	3	13	**1**	**75**	3	**79**	0	1	**3**	4	**155**
Total Volume	11	221	8	240	20	9	10	39	1	240	20	261	0	9	4	13	553
% App. Total	4.6	92.1	3.3		51.3	23.1	25.6		0.4	92	7.7		0	69.2	30.8		
PHF	.688	.891	.500	.938	.625	.750	.625	.650	.250	.800	.500	.826	.000	.750	.333	.813	.892

Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

File Name : Kaneohe Bay - Puohala (Nick's)
Site Code : 00000000
Start Date : 2/23/2010
Page No : 1

Groups Printed- Unshifted

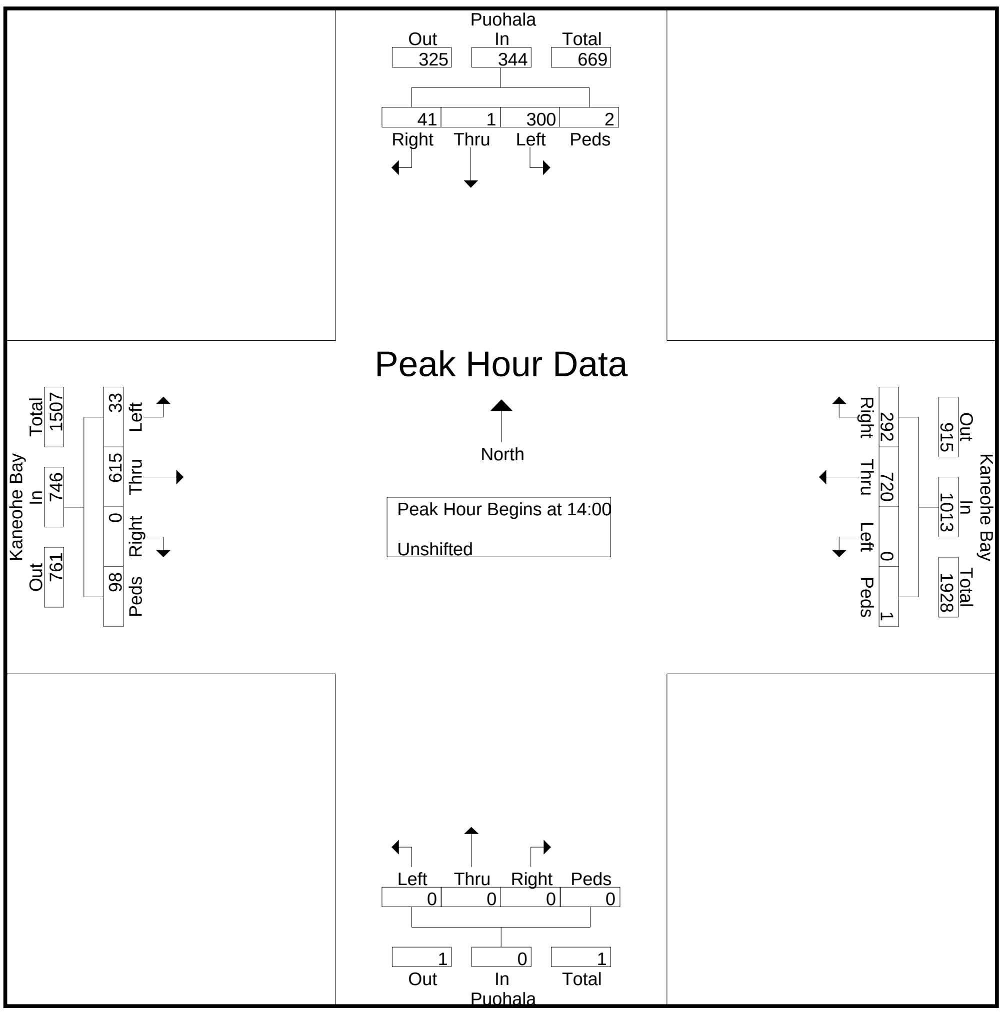
	Puohala From North				Kaneohe Bay From East				Puohala From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
13:45	7	0	64	0	68	126	0	1	0	0	0	0	0	122	9	4	401
Total	7	0	64	0	68	126	0	1	0	0	0	0	0	122	9	4	401
14:00	17	0	66	0	60	147	0	0	0	0	0	0	0	154	5	2	451
14:15	8	1	61	0	74	177	0	0	0	0	0	0	0	144	8	4	477
14:30	10	0	85	1	85	190	0	0	0	0	0	0	0	145	10	61	587
14:45	6	0	88	1	73	206	0	1	0	0	0	0	0	172	10	31	588
Total	41	1	300	2	292	720	0	1	0	0	0	0	0	615	33	98	2103
Grand Total	48	1	364	2	360	846	0	2	0	0	0	0	0	737	42	102	2504
Apprch %	11.6	0.2	87.7	0.5	29.8	70	0	0.2	0	0	0	0	0	83.7	4.8	11.6	
Total %	1.9	0	14.5	0.1	14.4	33.8	0	0.1	0	0	0	0	0	29.4	1.7	4.1	

Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

File Name : Kaneohe Bay - Puohala (Nick's)
Site Code : 00000000
Start Date : 2/23/2010

	Puohala From North					Kaneohe Bay From East					Puohala From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 14:00 to 14:45 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 14:00																					
14:00	**17**	0	66	0	83	60	147	0	0	207	0	0	0	0	0	0	154	5	2	161	451
14:15	8	**1**	61	0	70	74	177	0	0	251	0	0	0	0	0	0	144	8	4	156	477
14:30	10	0	85	**1**	**96**	**85**	190	0	0	275	0	0	0	0	0	0	145	**10**	**61**	**216**	587
14:45	6	0	**88**	1	95	73	**206**	0	**1**	**280**	0	0	0	0	0	0	**172**	10	31	213	**588**
Total Volume	41	1	300	2	344	292	720	0	1	1013	0	0	0	0	0	0	615	33	98	746	2103
% App. Total	11.9	0.3	87.2	0.6		28.8	71.1	0	0.1		0	0	0	0		0	82.4	4.4	13.1		
PHF	.603	.250	.852	.500	.896	.859	.874	.000	.250	.904	.000	.000	.000	.000	.000	.000	.894	.825	.402	.863	.894



Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

File Name : PM_Kaneohe Bay - Puohala
Site Code : 00000000
Start Date : 10/28/2009
Page No : 1

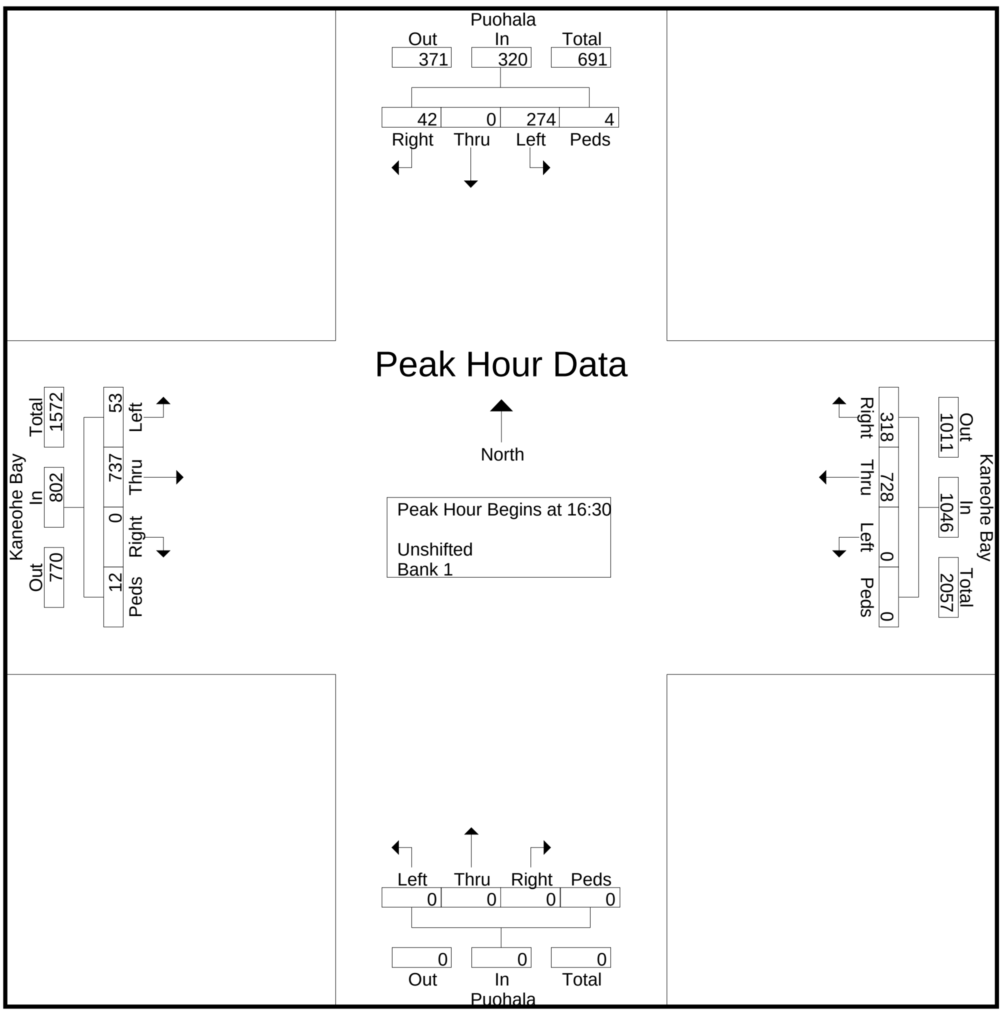
Groups Printed- Unshifted - Bank 1

	Puohala From North				Kaneohe Bay From East				Puohala From South				Kaneohe Bay From West				
Start Time	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Int. Total
16:00	8	0	67	0	74	173	0	0	0	0	0	0	0	178	13	2	515
16:15	10	0	84	0	67	197	0	0	0	0	0	0	0	188	23	2	571
16:30	8	0	68	0	75	161	0	0	0	0	0	0	0	186	11	0	509
16:45	11	0	68	2	92	192	0	0	0	0	0	0	0	197	14	2	578
Total	37	0	287	2	308	723	0	0	0	0	0	0	0	749	61	6	2173
17:00	14	0	65	0	67	187	0	0	0	0	0	0	0	161	15	3	512
17:15	9	0	73	2	84	188	0	0	0	0	0	0	0	193	13	7	569
17:30	8	0	57	1	54	165	0	0	0	0	0	0	0	162	11	2	460
17:45	15	0	49	0	74	191	0	0	0	0	0	0	0	168	17	0	514
Total	46	0	244	3	279	731	0	0	0	0	0	0	0	684	56	12	2055
Grand Total	83	0	531	5	587	1454	0	0	0	0	0	0	0	1433	117	18	4228
Apprch %	13.4	0	85.8	0.8	28.8	71.2	0	0	0	0	0	0	0	91.4	7.5	1.1	
Total %	2	0	12.6	0.1	13.9	34.4	0	0	0	0	0	0	0	33.9	2.8	0.4	
Unshifted	83	0	531	5	587	1454	0	0	0	0	0	0	0	1433	117	18	4228
% Unshifted	100	0	100	100	100	100	0	0	0	0	0	0	0	100	100	100	100
Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Bank 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Austin, Tsutsumi and Associates

501 Sumner Street, Suite 521
Honolulu, Hawaii 96817
ph: 533-3646 Fax: 526-1267

	Puohala From North					Kaneohe Bay From East					Puohala From South					Kaneohe Bay From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 16:30 to 17:15 - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 16:30																					
16:30	8	0	68	0	76	75	161	0	0	236	0	0	0	0	0	0	186	11	0	197	509
16:45	11	0	68	**2**	81	**92**	**192**	0	0	**284**	0	0	0	0	0	0	**197**	14	2	**213**	**578**
17:00	**14**	0	65	0	79	67	187	0	0	254	0	0	0	0	0	0	161	**15**	3	179	512
17:15	9	0	**73**	2	**84**	84	188	0	0	272	0	0	0	0	0	0	193	13	**7**	213	569
Total Volume	42	0	274	4	320	318	728	0	0	1046	0	0	0	0	0	0	737	53	12	802	2168
% App. Total	13.1	0	85.6	1.2		30.4	69.6	0	0		0	0	0	0		0	91.9	6.6	1.5		
PHF	.750	.000	.938	.500	.952	.864	.948	.000	.000	.921	.000	.000	.000	.000	.000	.000	.935	.883	.429	.941	.938



WILSON OKAMOTO
CORPORATION

ENGINEERS | PLANNERS | CONSULTANTS

1907 South Beretania Street Suite 400
Honolulu, Hawaii, U.S.A. 96826
www.wilsonokamoto.com
PH 808-946-2277 FX 808-946-2253