

Geographic Context

The Hawaiian Islands

The Hawaiian Islands are an archipelago of 132 islands, reefs, seamounts, and shoals strung in a 1,523 mile northwest-southeast alignment in the middle of the Pacific Ocean. It is almost 2,500 miles from the nearest landfall; the west coast of the U.S. mainland.

Eight islands make up almost 99 percent of the total land area of the island chain. Situated at the southeastern end of the archipelago, each of the main islands is a volcanic remnant that has been eroded by a combination of wind, rain, streams, and waves. The age of the islands trends from the southeast, so that Hawaii, the largest island of the chain, is the youngest and is still volcanically active, and Kauai and Niihau are the oldest and most eroded. Armstrong (1973:29, 32) describes the island-shaping process:

The major constructional landform is the typical, broadly rounded shield volcano built by innumerable thin lava flows. Commonly it has at its summit a large crater (caldera) formed by collapse of the mountaintop. ... Stream erosion first cuts small V-shaped gulches, and eventually great canyons, into the volcanoes. The most characteristic stream-eroded landform is the amphitheater-headed valley, with its steep walls and rounded head. ... Wave erosion cuts back the edges of the islands and forms sea cliffs. ... Locally, the wind has built sand dunes, especially where beach sand has been blown inland.

Sea level changes have also modified coastal areas. Sea level stands during periods of glaciation have varied as much as 500 feet. During one period of a higher sea stand, a broad coral reef formed along the southern shore of Oahu; when sea level dropped, the coral reef became the present Honolulu and Ewa Plains. During later periods of lower sea levels, "streams cut valleys into the reef, and as sea level rose again the mouths of the valleys were flooded to form Pearl Harbor" (Armstrong 1973:32).

The tropical climate of Hawaii is characterized by mild year-round temperatures and two basic seasons. Temperatures in Honolulu (roughly sea level) range from around 66 degrees F. in the winter to 90 degrees F. in the summer (Juvik and Juvik 1998). Temperatures rise with elevation, and temperature ranges vary significantly more at higher elevations than at sea level. The two seasons are winter from October to April and summer from May until September. Winter is a season of cooler temperatures, extensive rains, and more variable winds; the sun sits low in the sky. In the summer, the sun is almost directly overhead and the winds are persistently from the northeast (called the tradewinds).

The dominant northeast tradewinds combined with terrain features have a significant effect on rainfall patterns. As tradewinds hit the island mass, the mountains "obstruct, deflect, and accelerate the flow of air" (Armstrong 1973:54). As the warm, moist winds rise over the mountains, they form clouds and drop significant amounts of moisture onto the windward sides of the mountains. By the time the winds pass onto the leeward sides of the mountains, they have lost most of their moisture; the leeward sides of the mountains thus tend to be sunny, clear, and dry.

As a result of this orographic rainfall pattern, the islands are generally divided into wet windward and dry leeward sides. The windward sides of the island tend to have higher rainfall and permanent streams. The leeward sides of the islands tend to have lower rainfall and intermittent streams.

The islands were once characterized by distinct natural vegetation zones that have since been transformed by human use and modifications, beginning with the earliest Polynesian settlers of the islands (see Juvik

and Juvik 1998:122-123 for a graphical comparison of the native island ecosystems before human settlement and at present). Based largely on rainfall and elevation, these vegetation zones have been reconstructed based on existing vegetation, remnant native vegetation in disturbed areas, climatic patterns, and paleoenvironmental research.

Windward vegetation zones include lowland and montane sub-zones, with the montane zone extending into mountain bogs that occur in very wet, poorly-drained places near mountain summits (Cuddihy and Stone 1990). The native lowland wet forest would have been dominated by *ohia* (*Metrosideros polymorpha*) or *koa* (*Acacia koa*), with an understory of native trees such as *kopiko* (*Psychotria* spp.) and *hame* (*Antidesma platyphyllum*), the *ieie* vine (*Freycinetia arborea*), and a variety of ferns (depending on specific geographic locations). The native montane wet forest zone would have been dominated by a close-canopied *ohia* forest with a well developed understory of mixed native tree species, shrubs, and tree ferns. Bog vegetation is characterized by sedges and grasses.

Leeward vegetation is similarly divided into lowland and upland sub-zones. The native lowland dry zone would have been an open parkland type of forest, with extensive grasslands and shrubs (Kirch 1985). The forest would have included *wiliwili* (*Erythrina sandwicensis*), *naiio* (*Myoporum sandwicensis*), *lama* (*Diospyros ferra*), *ohe* (*Reynoldsia sandwicensis*), and sandalwood (*Santalum* spp.). Grasslands would have included *pili* (*Heteropogon contortus*) as well as endemic grasses that now have a much more restricted range. The native upper dry forest would have been dominated by *koa*, with an understory of shrubs and vines.

Other more geographically restricted zones include a relatively narrow coastal belt on all the islands and an alpine region on the four high mountains of Mauna Kea, Mauna Loa, and Hualalai on Hawaii Island and Haleakala on Maui.

Geographic Context Of Oahu

The island of Oahu is the third largest of the eight main islands and is the social, political, and economic center of the State of Hawaii. Land use is intensive, with large areas of the island developed in urban, industrial, residential, agricultural, and resort uses. Until recently, agriculture was an important component of the land use mix, but the decline of commercial sugar and pineapple has opened the way for more urbanization. USAG-HI installations occupy significant portions of the island, particularly the central plateau and the northern Koolau Range (see Appendix A, Map 1).

The island was formed by two major volcanic masses, the remnants of which are the Koolau and Waianae Ranges. The Schofield Plateau at the center of the island is the result of lavas from the Koolau Volcano flowing up against the landform of the older Waianae Volcano. The crest of the central plateau is over 880 feet above sea level (asl). The windward and leeward shores of the island are heavily eroded, with deeply indented amphitheater-headed valleys.

Sandy beaches encircle much of the island, with major fringing reefs on the windward and southern coasts. Uplifted coral exposures occur on the Ewa Plain (now an exposed limestone plain), along the leeward shore, and at a few localities on the north shore.

The South Coast

The south coast of the island is dominated by the rich estuarine waters of the centrally located Pearl Harbor lagoon. To the west of Pearl Harbor at the western end of the south shore is the arid coralline Ewa Plain. Immediately east of the harbor is the Moanalua Plain and the delta of Halawa Valley. Further east are small embayments at Keehi and Honolulu and the broad Honolulu-Waikiki Plain that ends at Diamond Head. Fringing reefs parallel a narrow coastal plain between Diamond Head with Koko Head, which marks the eastern end of the south shore.

The Ewa Plain lies at the foot of the Waianae Range. The area from Honolulu to Koko Head lies at the base of the Koolau Range. Between the two are the southern slopes of the central plateau. Small volcanic cones of late Koolau eruptions dot the south coast (from west to east): Puuokapolei and Makakilo on the Ewa Plain; Aliamanu, Aliapaakai, and Makalapa on the Moanalua Plain; Punchbowl in Honolulu; Leahi (Diamond Head) and Kaimuki above Waikiki; and Koko Head and Koko Crater at the east end of the coast.

The Hawaiian Islands underwent great changes in sea level during the Pleistocene, resulting in considerable modifications to the shorelines. During high stands of the sea, areas that are now exposed plains, such as at Ewa and Honolulu, were coral reefs under water. The Pearl Harbor lagoon is the drowned lower valleys of Waipio and Waikele Streams; these existed during a period of lower sea level.

Paleoenvironmental studies in the Fort Shafter area indicate that, prior to Polynesian settlement of the islands and roughly up through around A.D. 1000, the lower elevations of the southern Oahu coast was probably covered in “a lowland Pritchardia (*loulou*) forest with a high diversity of dryland to mesic forest types” (Wickler et al. 1991:51), including *kauila* (*Colubrina* sp.), *kukui* (*Aleurites moluccana*), *ahakea* (*Bobea* sp.), and *lama* (*Diospyros sandwicensis*). After A.D. 1000, however, the *loulou* forest declined rapidly and was virtually non-existent by the time of western contact.

USAG-HI installations on the southern shore of the island include Fort Shafter Military Reservation, Aliamanu Military Reservation, Tripler Army Medical Center, and Fort DeRussy Military Reservation.

The Leeward Coast

The leeward coast of the island from Kaena Point in the north to Kahe Point on the south is a series of deeply indented amphitheater-headed valleys carved into the western side of the Waianae Range. Falling in the rainshadow of the mountain range, the leeward valleys are generally arid, although there is great variability from shoreline to mountain crest: the coast and lower valleys are dry, with less than 20 inches of rain per year (Armstrong 1973); the interior valleys at the base of the range tend to be more lush, with perennial streams fed by springs and rainfall that in some places is over 40 inches per year (Cordy 1998); the crest of the mountain range behind the largest valleys receives 60 to 100 inches per year. Soils in the leeward valleys tend to be richer in the upper areas, where springs and higher rainfall have created small tributary valleys with alluvial deposits; the lower valleys have shallow alluvial soils.

The two largest valleys on the coast, Waianae and Lualualei, have large, flat-bottomed valley floors, cut by what were probably once permanent streams. The smaller valleys like Mākua have sloping floors that descend to narrow terraces along dry, deep streambeds.

The coast of Waianae is primarily a long stretch of white coralline sand with low dunes and narrow back dunes, interrupted by uplifted coral reefs that form rocky points and sometimes extend inland as limestone land. Before modern development, the back dune areas sometimes retained floodwaters that became narrow bands of swamps. Reefs extend a short distance from the shore and then drop off sharply into deep water.

Mākua Military Reservation and the Waianae Army Recreation Center (Waianae Kai Military Reservation) are located on the leeward coast of Oahu.

The North Shore

The north shore of the island extends from Kaena Point on the west to Kahuku Point on the east. Sandy beaches line most of the north shore, with fringing reefs just west of the town of Haleiwa and at the

eastern end of the shoreline by Kahuku Point (Juvik and Juvik 1998). At the western end of the north shore, elevated coral reefs interrupt the stretches of narrow coastal sand.

Annual rainfall along the north shore is low, varying from between 20 to 30 inches at the western end to up to 50 inches at the eastern end (Anderson 1997).

The Waianae Range parallels the western half of the north shore, coming to its end at Kaena Point. The Koolau Range comes to its end at Kahuku Point. Both ranges drop sharply to a level coastal plain. There are no permanent streams coming out of the Waianae Range and only a few in the Koolau Range. However, springs at the base of the ranges are sources of fresh water.

At the center of the north shore is Waialua Bay, into which flow some of the longest streams on the island, all originating out of the Koolau Range. Kaukonahua Stream, however, meanders from its origin in the Koolaus across the central plateau and then along the base of the eastern Waianae Range, capturing the waters from the upper Waianae gulches.

USAG-HI installations on the north shore include Dillingham Military Reservation and Mokuleia Army Beach at the base of the Waianae Range.

The Central Plateau

The Schofield Plateau forms the central mass of Oahu. The crest of the plateau is more than 880 feet asl. The central plateau is the result of Koolau lavas flowing up against the mass of the older Waianae Volcano. Although streams from both ranges have cut narrow drainages from the crest of the plateau to the north and south shores of the islands, the sloping landform remains relatively undissected.

The longest stream on the island, Kaukonahua Stream, flows west from the Koolau Range to the middle of the central plateau and then drains north into the ocean at Waialua. Streams emanating out of the eastern Waianae Range are tributaries to Kaukonahua.

The eastern portion of the plateau coming out of the Koolau Range is rugged and dissected, carved by numerous streams separated by narrow ridges. In contrast, the western portion of the plateau abutting the Waianae Range is undulating, with broad slopes cut by a few, well-defined drainages. Kolekole Pass is a low point on the Waianae Range at 1,724 feet asl and is a long-time transportation route to the leeward coast.

Based on rainfall and elevation, the central plateau can generally be characterized as part of the lowland dry and mesic forest zone (based on Cuddihy and Stone 1990). Present-day remnant forests of this zone are dominated by *lama* (*Diospyros sandwicensis*) or *ohia lehua* (*Metrosideros polymorpha*). Other trees of this zone include *wiliwili* (*Erythrina sandwicensis*), *koa* (*Acacia koa*), and *kaulu* (*Sapindus oahuensis*).

The training ranges and cantonment of Schofield Barracks Military Reservation are situated at the crest of the central Oahu plateau. On the southern slope of the plateau are Wheeler Army Airfield, Kunia Field Station, the Kipapa Ammunition Storage Site, and the Waikakalaua Ammunition Storage Tunnels Site. On the northern slope is the Helemano Military Reservation and the Pupukea-Paalaa Uka Road.

The Mountain Ranges

The Waianae and Koolau Mountains are parallel ranges that are the remnants of the calderas of the two volcanoes that formed the island of Oahu.

The Koolau Mountains capture most of the orographic rainfall that hits the island of Oahu. The deeply incised valleys of the windward coast are drained by permanent streams that flow out of the highly

sculpted, sheer Koolau cliffs. The leeward side of the northern range is a rugged mountainous area of steep slopes, narrow ridges, and deep, meandering gulches with streams that run permanently to the ocean at Waialua Bay. Rainfall, at the highest elevations of this area, reaches up to 250 inches per year (Dega and McGerty 1998). On the leeward side of the southern range are the lush amphitheater-headed valleys behind the Honolulu-Waikiki Plain. The highest point on the Koolau Range is the 3,150 foot high Konahuanui Peak above Manoa Valley in the southern portion of the range.

The higher elevations of the northern Koolau Range include stands of *ohia* (*Metrosideros polymorpha*) and *koa* (*Acacia koa*) (Dega and McGerty 1998). The gulches retain some *koa*; economic plants that are known to have been used by ancient Hawaiians include breadfruit (*Artocarpus altilis*), pandanus (*Pandanus* sp.), coconut (*Cocos nucifera*), ti (*Cordyline fruticosa*), noni (*Morinda citrifolia*), and banana (*Musa* spp.) (Kirch 1992).

The Waianae Mountains are the older of the two ranges and considerably drier than the Koolau Range. Mount Kaala, on the crest of the Waianae Mountain, is the highest point on the island, standing at 4,003 feet asl. Two low points on the range, Kolekole and Pohakea, were used by ancient Hawaiians as trail routes between the central plateau and the leeward coast; the former remains a transportation route in the form of the Army-built Kolekole Pass Road.

Located in the mountain ranges of Oahu are Kahuku Training Area and Kawaihoa Training Area in the northern Koolau Mountains, and the Mauna Kapu Communications Station in the southern Waianae Mountains.

Geographic Context Of Hawaii

The island of Hawaii is the largest of the Hawaiian archipelago, but is one of the least densely occupied. The urban hubs are Hilo on the east coast and Kailua-Kona on the west coast. Much of the remainder of the island is unurbanized, taken up by the Hawaii Volcanoes National Park, the USAG-HI Pōhakuloa Training Area, agricultural and pasture lands, and lava flows.

The island is composed of five volcanoes, of which two (Mauna Loa and Kilauea) remain active; a third volcano (Hualalai) last erupted in 1801 and, while presently dormant, may erupt again (Macdonald et al. 1983). Mauna Kea is the highest point in the state, standing at 13,796 feet asl, with Mauna Loa a close second at 13,677 feet asl. It is not uncommon to have winter snowfall on both mountain tops. Extensive areas of the slopes of the three volcanoes remain open expanses of hardened lava, and much of Mauna Loa and Kilauea are considered high volcanic hazard zones by the U.S. Geological Service (Juvik and Juvik 1998).

At the center of the island is the high-elevation Saddle Region or inland plateau, formed by the convergence of lavas from the three active volcanoes.

Typical windward coastal amphitheater-headed valleys occur only in the northern part of the island, which was formed by the oldest volcano, the present Kohala Mountains. To the south along the Hamakua coast, narrow, steep-sided gulches, separated by broad, undissected ridges, emanate out of the more recent Mauna Kea summit.

The island coastline is considerably rockier than on Oahu, with extensive stretches of sheer sea cliffs, particularly along the windward coast. There are few and very localized occurrences of sandy beaches. There is virtually no major fringing reef on the island. The coastal embayments at Hilo on the windward coast and at Kealahou and Kawaihae on the leeward coast offer the few protected anchorages on the island.

The Saddle Region

The high-elevation Saddle Region of the island of Hawaii sits between the three highest mountains of the island, Mauna Kea, Mauna Loa, and Hualalai. Elevation at the Pōhakuloa Training Area, located on the saddle, ranges from about 4,000 to 8,800 feet asl. Large areas of the saddle are pahoehoe and aa lava flows from Mauna Kea and Mauna Loa, with most flows from the latter volcano. The flows contain subsurface features such as lava tubes and lava blisters; the lava tubes form extensive and sometimes interconnected networks of underground passageways that are accessed from the surface by collapsed openings. Some of the pahoehoe flows formed surface chills of volcanic glass, which was a valuable resource for early Hawaiians. Other volcanic constructs in the Saddle Region include *pu'u* (spatter or scoria cones). Older land surfaces are preserved in *kīpuka*, which are islands of pre-existing terrain and vegetation that were preserved when a flow of lava split into two flows for a short distance and then regrouped into a single flow.

Annual rainfall averages from 4 to 16 inches; fog, hail, and occasional frosts also occur. Temperatures average about 60 degrees F. in the lower elevations and 50 degrees F. in the higher elevations.

Vegetation on the saddle is a xerophytic scrub type and largely varies by the age and type of lava flow. Recent flows are typically barren. Older flows are usually dominated by open *ohia* forests or a mix of several plant species. *Kīpuka* (a vegetated pocket in a lava flow) usually have a scrub forest of *mamane* (*Sophora chrysophylla*) and *naio* (*Myoporum sandwicense*). Native shrubs include *akia* (*Wikstroemia* sp.), *pukiawe* (*Styphelia tameiameia*), *aalii* (*Dodonaea eriocarpa*), *kolea* (*Myrsine lanaiensis*), and sandalwood (*Santalum* sp.) (Williams [ed.] 2000).

Kilauea Volcano Summit

The summit of the Kilauea Volcano lies at about 4,000 feet asl. The volcano is the youngest and most active of the five volcanoes that make up the island of Hawaii. From 1823 to 1924, the Halemaumau pit crater within Kilauea was continuously active, with lava at times filling the entire floor of the main crater. From 1924 until 1982, activity was sporadic but with periodic fiery displays. In the immediate vicinity of Kilauea Military Camp, which is the only USAG-HI installation in the summit region of the volcano, no new lava has flowed during recorded times, although debris from explosive eruptions in 1790 and 1924 are scattered around the rim.

Although Halemaumau pit crater is the most obvious and dominating feature of the Kilauea summit landscape, steam vents and earthquake cracks along the north rim of the crater add an imposing character with hot steam rising from yawning, seemingly bottomless crevices. The cracks, especially those obscured by dense rainforest vegetation, are particularly dangerous hazards. The steam vents are some of the few sources of drinkable water (other than by collecting rainfall) in the summit area. Steam rising from the vents is condensed by the cool mountain air and the resulting water can be collected from drips along the edges of the cracks.

Distribution and intensity of rainfall in the volcano region is tied to orographic conditions. Doty and Mueller-Dombois (1966:47) note that rainfall drops markedly to the west of “the ridge formed by Kilauea and its east rift, especially near and above the 3000 foot level.” At the Hawaii Volcanoes National Park headquarters, average rainfall is about 93 inches, while a few miles to the southwest and 300 feet lower, the average rainfall is about half that measure. Kilauea Military Camp lies at the approximate rainfall divide.

The effect of this rainfall pattern is reflected in the vegetation of the summit region. The dominant montane rainforest of the eastern side of the divide is characterized by “a pure stand of *Metrosideros* trees, with diameters at breast height of 40-65 cm and uniform crown-canopy heights ranging between 14 and 20 m,” with a dense understory of *hapuu* (tree fern, *Cibotium* spp.) (Doty and Mueller-Dombois

1966:409-410). To the west of the divide, the vegetation of the drier climate is represented primarily by an open forest of 3 to 10 m high *ohia* trees, whose distribution and density is largely controlled by the occurrence of the pahoehoe cracks in which these trees grow (Doty and Mueller-Dombois 1966). Lichens and low native shrubs such as *aalii* (*Dodonaea viscosa*), *pukiawe* (*Styphelia taimaiamaia*), and *kupaoa* (*Dubautia scabra*) grow in shallow soil and ash deposits that collect in depressions in the lava.

Temperature at the north rim of the crater ranges from a minimum of 40 degrees F. during the winter to a maximum of 74 degrees F. during the summer (Doty and Mueller-Dombois 1966).

The Leeward Coast

Kawaihae Military Reservation is located on the leeward west shore of the island at Kawaihae Bay. The primary modern feature of this bay is the Kawaihae Small Boat Harbor and the adjacent small commercial community.

The bay lies at the base of the southwestern slopes of the ancient Kohala Volcano, from which its volcanic soils derive. The leeward side of the Kohala Mountain drops in a relatively steep and undissected slope to a rocky coastline. There are few, widely spaced erosional gullies; two gullies drain into Kawaihae Bay at the southern end of the modern harbor.

Rainfall in this area is less than 10 inches per year. Vegetation is limited to xeriphytic growth, primarily shrubs and grasses, with some trees. The normally dry gulches flow only during periods of heavy rains. Available water in this area is brackish.

Clark (1983:63) writes:

While aridity is one dominating characteristic of [this] ... region, the other is its proximity to the sea. Kawaihae has long provided an excellent port for both Hawaiian and later, Euro-American vessels. In addition, it is an area rich in marine resources – near-shore, reef, and offshore. It is here that the true wealth of Kawaihae lay.

The Windward Coast and Hilo Bay

The SFC Minoru Kuneida U.S. Army Reserve Center is located adjacent to Hilo Airport on the windward east coast of the island. The city of Hilo wraps around an L-shaped bay of the same name. Behind Hilo, the land rises gradually to the Saddle Region and Mauna Loa. The area just west and north of the town of Hilo is the wettest on the island, receiving an average annual rainfall of over 240 inches. Hilo town receives about 160 inches of rain a year (compare this with the less than 10 inches of rain per year at Kawaihae).

To the south of the bay, the land is relatively level and densely vegetated; it consists of pahoehoe and aa lavas primarily from Mauna Loa. The coastline is rocky. To the north of the bay, the land rises steeply up the eastern slopes of Mauna Kea; it is heavily dissected by numerous narrow, steep-sided streams. In marked contrast with the southern shoreline, the coastline to the north of Hilo consists of sheer sea cliffs. The coastal gulches are notable for their precipitous character.