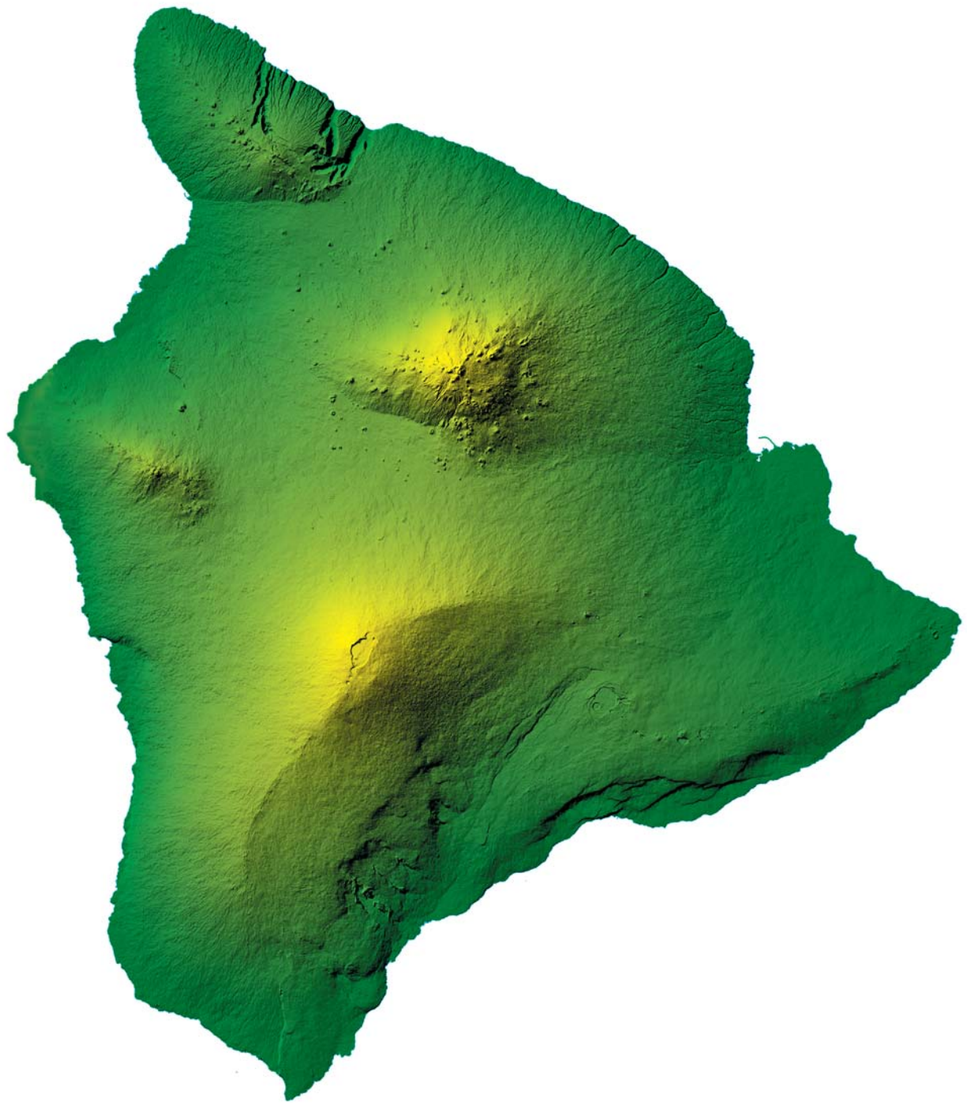
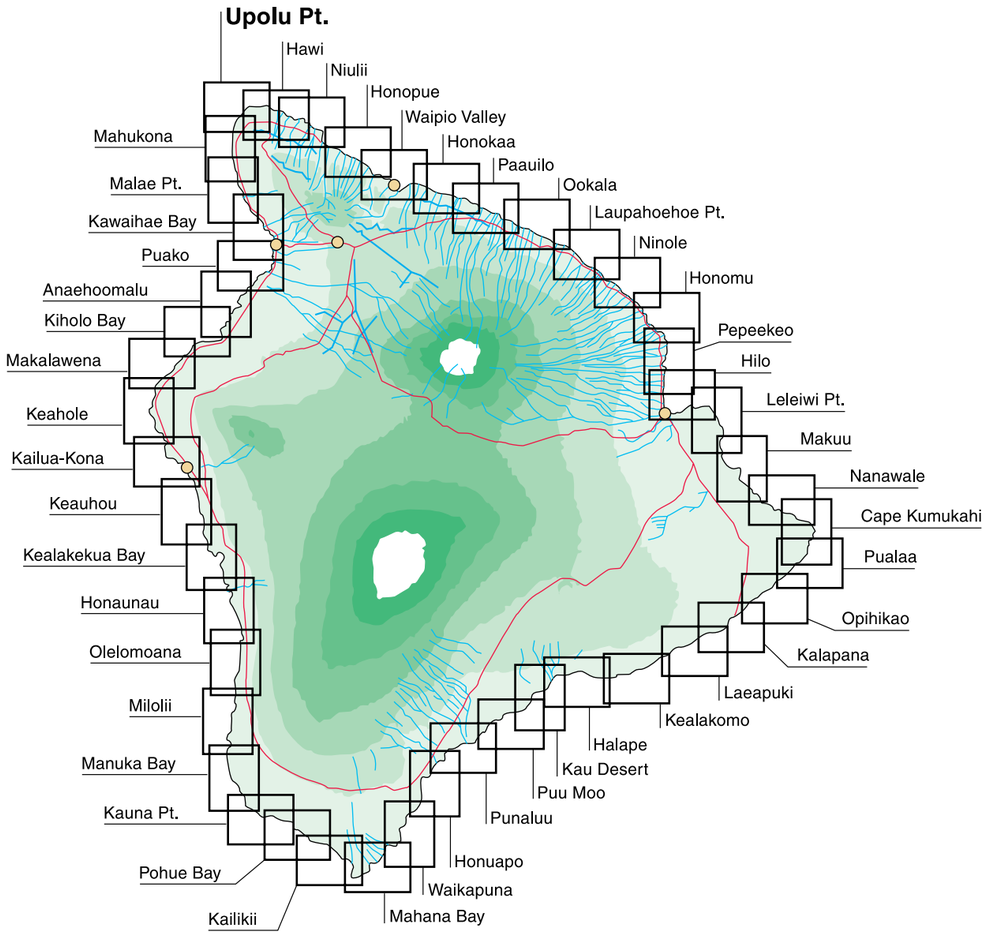
Hawaii

The Big Island of Hawaii is the youngest and largest of the Hawaiian Islands. Volcanism has historically been very active on Hawaii and since 1983, Kilauea volcano has steadily erupted and sent numerous lava flows down its east and southeast flanks to the sea. These volcanic eruptions continue to enlarge the Big Island. Recent studies, however, indicate that the islands grow with episodic and often catastrophic landslides that may result in large portions of the volcano being spalled off into the sea like calving glaciers. Lava flows extend the shoreline out into the sea, sometimes at the expense of pre-existing coastal lands and settlements. For example, in 1992 lava flows buried the famous Black Sand Beach and the town of Kalapana as they formed a new coastal terrace and extended the shoreline 0.5 mi seaward. Periodically, the island foundations do not adequately support these coastal terraces, and rapid collapse or landsliding results in loss or abrupt subsidence of the coastal zone. Such events are known to produce devastating tsunamis, like those of 1868 and 1975 that inundated portions of the southeast coast of the Big Island. Earthquakes are common on the Big Island owing to the movement of magma within the volcanic edifice. Although the Big Island is geologically young, deep valleys carved into its mountain sides attest to active stream erosion. During high rainfall, floods are common along low-lying coastal zones.



Hawaii

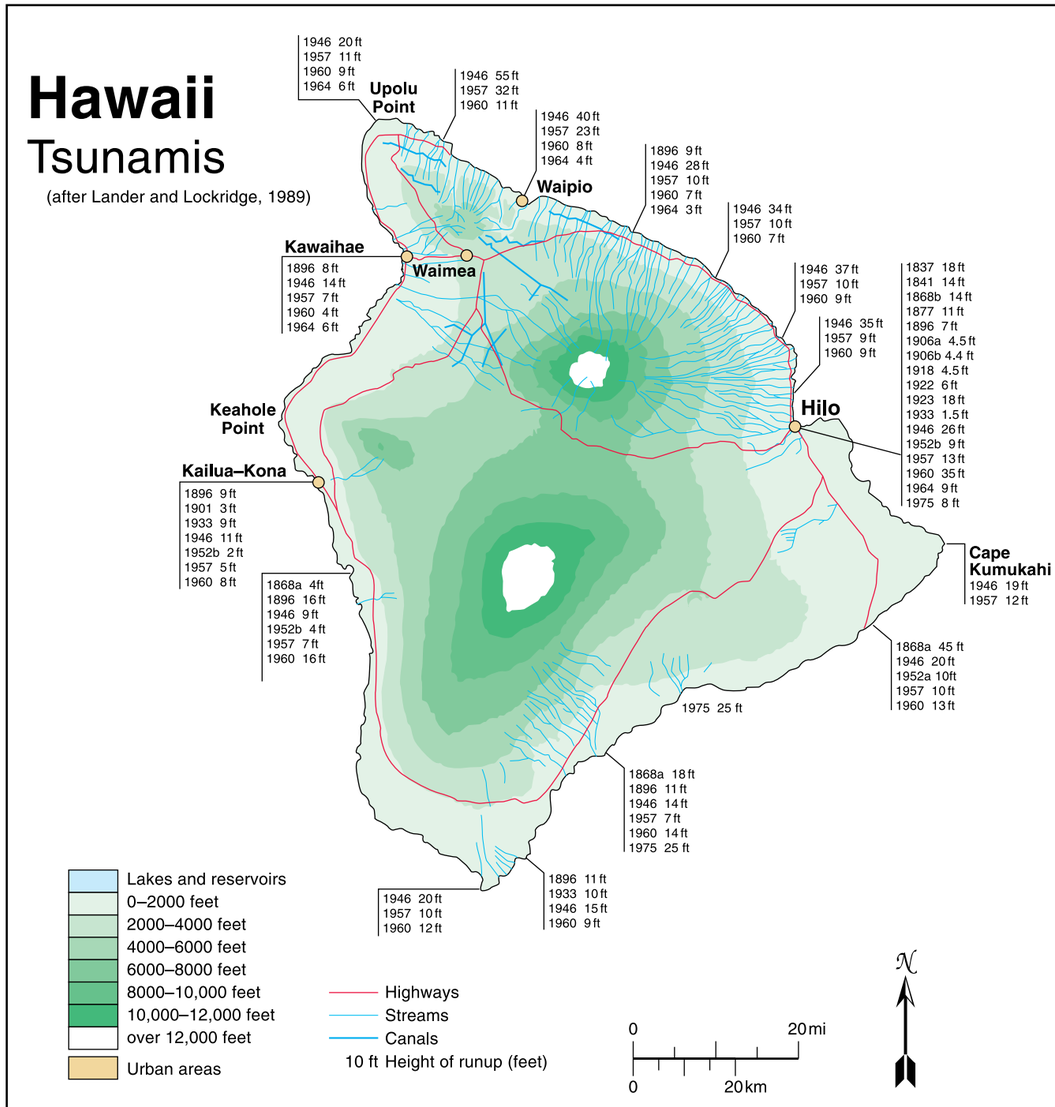
Index to Technical Hazard Maps



Tsunamis

A tsunami is a series of great waves most commonly caused by violent movement of the sea floor. It is characterized by high speed (up to 590 mph), long wave length (up to 120 mi), long period between successive crests (varying from 5 min to a few hours, generally 10 to 60 min), and low height in the open ocean. However, on the coast, a tsunami can flood inland 100's of feet or more and cause much damage and loss of life. Their impact is governed by the magnitude of seafloor displacement related to faulting, landslides, and/or volcanism. Other important factors influencing tsunami behavior are the distance over which they travel, the depth, topography, and morphology of the offshore region, and the aspect, slope, geology, and morphology of the shoreline they inundate. While storm-derived waves affect the shore in a generally predictable manner, tsunami waves are more chaotic. Hilo has experienced more damaging tsunamis than any other Hawaiian coastal city during recorded history. It is important to understand that tsunami waves are very different from ordinary storm waves in that their broad crests enable the water level to rise for several minutes as they pass. As a result, tsunami waves can inundate significantly farther inland than storm-generated waves of the same height. The only general rule is that runup heights tend to be greatest near headlands where the offshore bathymetry is steeper. This enables greater wave energy to reach the shore. Along gently sloping coasts, even though runup heights may be reduced due to dissipation offshore, inundation is greatest because the wave can push farther inland.

Since 1812, 26 tsunamis have had damaging consequences to Hawaiian shorelines. Of these, 25 (74%) have adversely impacted the Big Island of Hawaii. Four of these damaging tsunamis were generated by seismic displacements along Kilauea's southeastern flanks, the most recent being the 1975 Halape Earthquake. On November 29, 1975, the strongest earthquake measured in Hawaii this century caused approximately 10 ft of subsidence along the Halape coastal terrace. It produced a local tsunami wave that reached at least 25 ft in height and devastated the Halape area of the southeast coast within minutes. It sadly brought an end to the lives of two people camped at Halape. There was no warning and no time to respond. A similar local tsunami occurred on April 2, 1868, which washed away fishing villages and shipping facilities and in places displaced the nearshore seafloor such that shipping lanes could no longer be utilized. The remaining 22 damaging tsunamis traveled 1000's of miles from tectonically active regions of the Pacific including Alaska, and the Aleutian Islands, Chile, Japan, and Tonga. Even though most of these tsunamis took 10's of hours to reach Hawaiian waters from their distant source areas, very little warning, if any, was available, largely because very few islands exist between Hawaii and the Pacific Rim which could be used to detect their approach. Today, technologies including seafloor seismic and wave (pressure) sensors exist that can provide adequate warning. One of the most devastating of these distant tsunamis occurred on April 1, 1946. Runup heights of >9 ft were measured on all sides of the island and the maximum of 55 ft was reported near Upolu Point. In Hilo, the wave rushed up 26 ft and inundated the low-lying ocean front causing extensive damage, which would be relived by the 1957 and 1960 tsunamis. According to the historical database, on average a damaging tsunami reaches the Big Island's shores once every 7 years. Interestingly, the last 25 years have been extremely quiet; since 1975, not one tsunami has made landfall. Based on these data, one would conclude that a damaging tsunami is long overdue to hit the Big Island's coastal zone.



Large tsunamis* (>1m, 3.3 ft) with reported damage in the Hawaiian Islands

Year	Date	Area of origin	Magnitude**
1819	Apr 12	N Central Chile	M= 2.0
1835	Feb 20	Southern Chile	M = 4.0
1837	Nov 7	Southern Chile	M = 3.0
1841	May 17	Kamchatka	M = 2.0
1868a	Apr 3	SE Hawaii	M = 4.1
1868b	Aug 13	Northern Chile	M = 4.3
1868c	Oct 2	South Pacific	
1869	Jul 24	South Pacific	
1877	May 10	Northern Chile	M = 4.0
1878	Jan 20	Aleutian Is (?)	
1896	Jun 15	Japan	M = 4.0
1901	Aug 9	Tonga	
1906a	Jan 31	Colombia/Ecuador	M = 1.0
1906b	Aug 17	Central Chile	M = 2.0
1918	Sep 7	Kurils	M = 3.6
1919	Oct 2	Hawaii (H = 14 ft)	
1922	Nov 11	N Central Chile	M = 3.0
1923	Feb 3	Kamchatka	M = 3.0
1933	Mar 2	Japan	M = 3.0
1946	Apr 1	Eastern Aleutian Is	M = 5.0
1952a	Mar 17	Hawaii (H = 10 ft)	
1952b	Nov 4	Kamchatka	M = 4.0
1957	Mar 9	Central Aleutian Is	M = 3.5
1960	May 22	Chile	M = 4.5
1964	Mar 28	Gulf of Alaska	M = 4.5
1975	Nov 29	Big Island/Hawaii (H = 47 ft)	

*Reliability of ≥ 3 (of 4)(Lander and Lockridge, 1989), runup > 1m (3.3 ft), and reported damage.

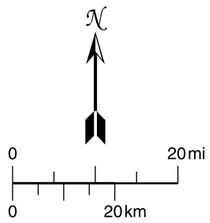
** Tsunami magnitude is defined by $M = \log_2 H$ as revised by Iida and others (1967), where H is the maximum runup height or amplitude on a coastline near the generating area.

Other tsunamis have occurred, such as that of Oct 1994, however, because of their low (<1 m) runup, insignificant damage, and/or uncertainty surrounding their timing and magnitude as noted in Lander and Lockridge (1989), they were not included here.

Hawaii
Stream flooding

Islandwide stream flooding because of heavy rains

1959 Aug 4–7 H Dot
1979 Feb 19–20 Flooding
1979 Dec 14–18 Flooding
1980 Mar 6–25 Episodes of flooding
1981 Oct 27–28 Flash flooding
1982 Jul 21–22 TD Daniel, flash flooding
1984 Dec 24–25 Kona storm, flooding
1986 Apr 8 Flooding
1986 Nov 10–11 Flooding
1987 Jul 21–23 Flooding
1987 Dec 11–19 Flooding
1988 Mar 14–18 Flooding
1988 Aug 4–8 H , flooding
1989 Feb 3–5 Flooding
1989 Mar 1–4 Flooding
1989 Jul 18–20 TS Dalilia, flooding
1990 Jan 14–22 Flooding
1992 Sep 14 TS Orlene, flooding
1992 Nov 29 widespread flooding
1993 Jul 21–22 TS Dora, flooding



Lakes and reservoirs
0–2000 feet
2000–4000 feet
4000–6000 feet
6000–8000 feet
8000–10,000 feet
10,000–12,000 feet
over 12,000 feet
Urban areas
Highways
Streams
Canals

11" Max. rainfall from storm (inches)
1070 cfs Max. peak discharge (ft^3 per sec)
5 ft Max. height of flooding (feet)
—30— Mean annual rainfall (inches)

[H, hurricane; R, river; Str, stream; TD, tropical depression; TS, tropical storm]

Kohala

1918 Apr 9–10 Flash flooding
1936 Jan 17 Flash flooding at N. Hi
1966 Nov 20 Flash flooding at S. Kohala
1967 Jan 11 Flooding
1982 Aug 9–10 Flash flooding
1983 Dec 24–26 Flooding
1986 Feb 16 Localized flooding
1986 Apr 8 Flooding at Waimea, Kohala
1889 Feb 3–5 Flash flooding at Pahala
1989 Apr 28–29 Flash flooding at Waimea
1991 Aug 5–7 Flash flooding
1996 Sep 8–9 Flash flood
S. Kohala and Waikaloa
1997 Jan 5 Widespread floods
Waikaloa Village

Waipio Valley

1902 Mar 6 Flash flooding
1972 Aug 18–Sep 3 Flash flooding
1978 Dec 6 Flooding
1979 Dec 14–18 Severe flooding
1989 Apr 4–9 Flooding
1991 Aug 5–7 Flooding

Hamakua Coast

1890 Dec 9 Flash floods at Hamakua, Honokaa
1902 Mar 6 Flash floods at Hamakua
1965 Aug 4–5 Sheet flows
1982 Jul 16–17 Flash flooding at Hamakua
1982 Aug 1 TD Gilma, flash flooding
1982 Aug 9–10 TS John, flash flooding at Honokaa
1983 Oct 26 Hamakua Coast
1984 Feb 8 Flooding
1985 Mar 11 Flash flooding
1986 Mar 16 Flash flooding
1986 Apr 3 Flash flooding
1986 Apr 8 Flooding
1986 Sep 26 Flash floods, 6–10" rain
1987 May 5–6 Extensive flash flooding, over 10" rain
1987 Oct 1 Flooding, 10–15" rain
1987 Nov 21 Flash flooding
1988 Mar 14–18 Flooding, 5–10" rain
1989 Apr 28–29 Flooding at Honoka'a
1989 Aug 20–21 Minor flash floods
1990 Dec 18–20 Flooding
1991 Aug 5–7 Flooding
1994 Apr 11–12 Floods, landslides

Hilo / Puna

1928 Oct 1 Flash flood of Wailuku R.
1966 Jul 25 Sheet flow
1967 Aug 2–11 Flash flood, 12" rain
1971 Apr 23 Flash floods, 9.66" in 24 hrs
1979 Feb 19–20 Flooding at Hilo, Keeau, Pahoa, Kurtistown
1980 Mar 18 Flooding
1980 Sep 20–22 Flooding
1982 Mar 30–31 Flooding, 10" rain
1982 Jul 16–17 TS Emilia, flash flooding
1982 Jul 23 Flash flooding, 29" rain in July
1982 Aug 1 TD Gilma, flash flooding
1984 Nov 3–4 Flooding, 4–6" rain
1985 Sep 25 Flash floods
1986 Apr 3 Flash floods
1986 Sep 26 Flash flooding, 6–10" rain
1986 Nov 8 Flash flooding, 10" rain
1987 Oct 1 Flooding, 10–15" rain
1988 Aug 4–8 H Fabio, flooding in Hilo and Kurtistown
1990 Nov 18–20 Flooding, 30" rain
1991 Aug 3–4 Flash flood, 11" at airport
1992 Sep 14 TS Orlene, widespread flood
1993 Oct 3 5–7" rain Puna and Hilo
1994 Apr 11–12 Floods, landslides
2000 Nov 1-2 Flooding, landslides, 25" in 24 hrs

Kailua–Kona

1918 Apr 18 Flash flood at Kona sugar mill
1922 Oct 22 Flash floods at South Kona
1930 Jan 25 Holualua reservoir burst, flash floods
1961 Oct 30 Flash floods at South Kona
1963 Apr 29 Flash floods at Kaimaliu
1965 Sep 25 Capt. Cook, Kaimaliu
1966 Oct 3–5 Flash floods at Capt. Cook & Holualua
1967 Oct 12 Overland flow at Ho'okena
1967 Oct 24 N. Kona
1968 Jul 17 Local flash flooding at Kealakekua
1968 Oct 3 Flash floods at N. Kona
1974 Oct 15 Flooding Kaloloa to Honaunau, 4.5" in 7 hrs
1976 Apr 26 Flash flooding Honaunau
1982 Mar 17 Minor flooding at Kona
1985 Sep 29 Flash flooding Capt. Cook to Kealakekua
1985 Nov 19
1986 Feb 16 Localized flooding at N. Kona
1989 Feb 3–5 Flash flooding at S. Kona
1992 Sep 17 Heavy thunderstorms, minor flooding
1996 Jun 22 2.1" in 1 hr, widespread flooding
1997 Jan 5 Widespread floods, Captain Cook to Kealakekua

Kau

1917 Mar 19 Flash flood
1945 Apr 8 Flash flood
1962 Mar 13–15 Overland flow at Palaha
1980 Mar 18 Flooding
1982 Jul 16–17 TS Emilia
1982 Aug 1 TS Gilma
1985 Nov 19 Minor flash flooding in Kau district
1986 Nov 8 Flash floods, 10" rain
1989 Jul 18–20 TS Dalilia flooding
1990 Jan 14–22 Flooding, over 20" rain
1990 Sep 14–28 Flooding
1990 Nov 18–20 Flooding, 30" rain

South Point

1967 Nov 26–27 Severe flooding at Naalehu
1979 Feb 19–20 Naalehu & Pahala, 22.3" in 24 hrs

Upolu Point
Kawaihae
Waimea
Keahole Point
Kailua–Kona
Hilo
South Point

Stream flooding

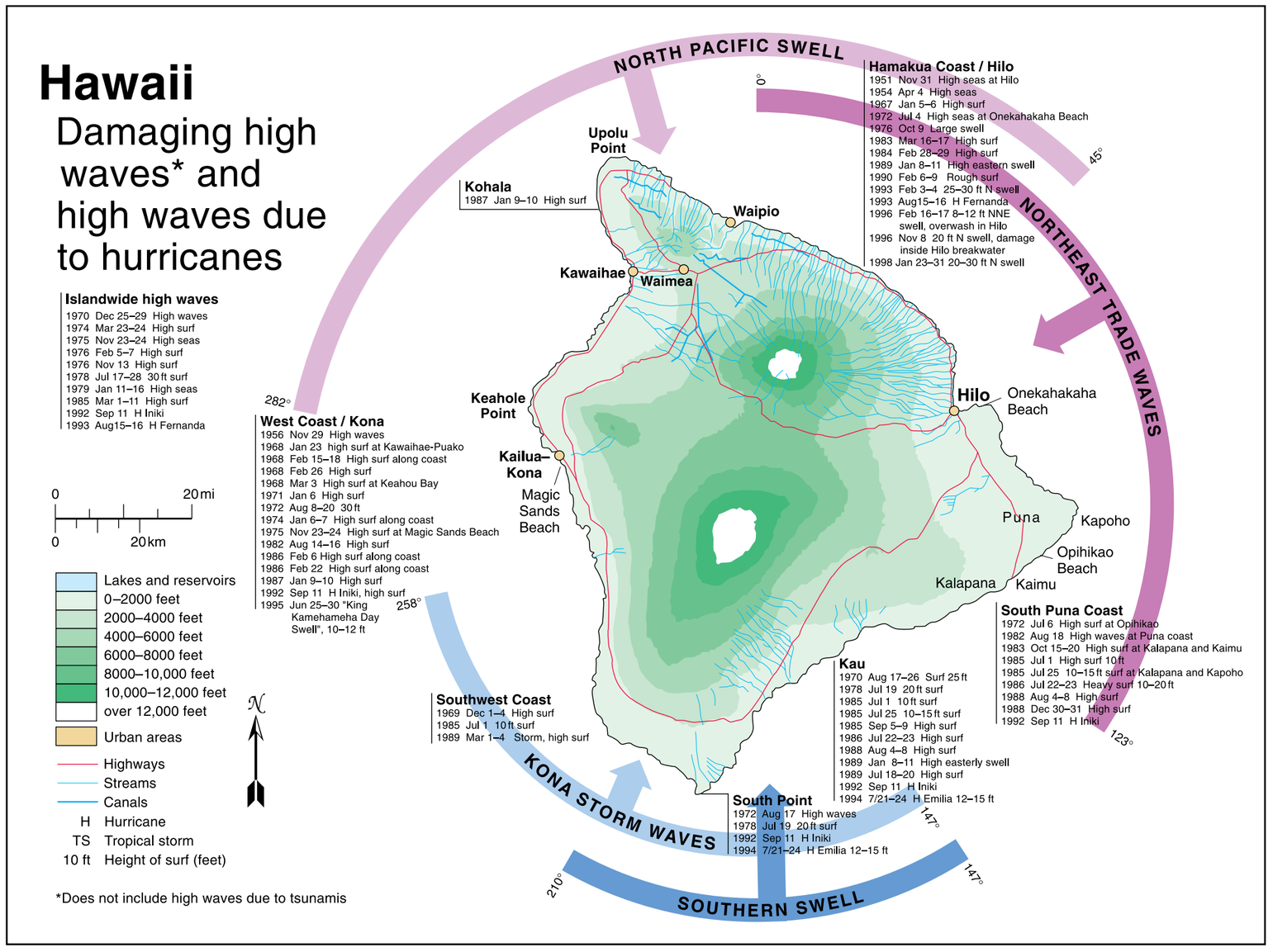
Stream flooding in the coastal zone of the Big Island of Hawaii results from heavy precipitation on the steep mountain slopes of Mauna Kea, Mauna Loa, and Kohala, as well as flash flooding from extraordinary rainfall events on the coastline itself. Kilauea and Hualalai volcanoes are located in more arid regions but occasionally do receive intense rainfall that causes flash floods downslope. Annual rainfall ranges between 300 in on the slopes of Mauna Kea above Hilo, to below 10 and 20 in in the arid regions of Kawaihae and South Point. Soils that can absorb precipitation are better developed on the older volcanoes of Kohala and Mauna Kea, so mudslides and landslides are more common along the coastal cliffs of the Waipio and Hamakua Coasts. The young lavas that comprise the coastal terraces of Mauna Loa, Kilaeua, and portions of Hualalai, are very porous and have less soil development. Often, heavy precipitation simply infiltrates into the rock and flows toward the sea in underground streams. As a result, stream flooding is generally less of a hazard on the younger coastlines and requires flash flooding due to intense rainfall events to produce overland runoff.

Many occurrences of islandwide stream flooding have been reported since 1959, and many are associated with precipitation associated with passing tropical storms and hurricanes or their remnants. Flooding along the wet, windward side of the island has been common and rather expected due to the large input of rainfall. Much of the windward coastline is relatively steep and so runoff occurs in deep channels that reach the shore below steep cliffs. Most of the flooding that has caused damage has been flash flooding during extreme rainfall events that bring about sheet flow between stream channels. The Hilo and Puna areas are probably the most frequently flooded and hardest hit by flash floods on the Big Island and perhaps in the state. On November 18-20, 1990, 30 in of rain fell in the region bringing about intense flooding of the low-lying coastal areas. What is more surprising is the degree of flooding that the more arid regions of the Big Island have sustained. The Kohala and Kailua-Kona Coasts have a long and active history of flooding largely due to flash flooding and intense storms. From 1997 to 2001, the South Kohala and Waikaloa areas have experienced intense flash flooding that has caused considerable damage. According to the data from the last 50 yr, on average a damaging flood event occurs on the Big Island every 2 yr. During this past 50 yr, however, the threat due to stream flooding has increased dramatically because of the risk taken to develop extensively in flood prone areas.

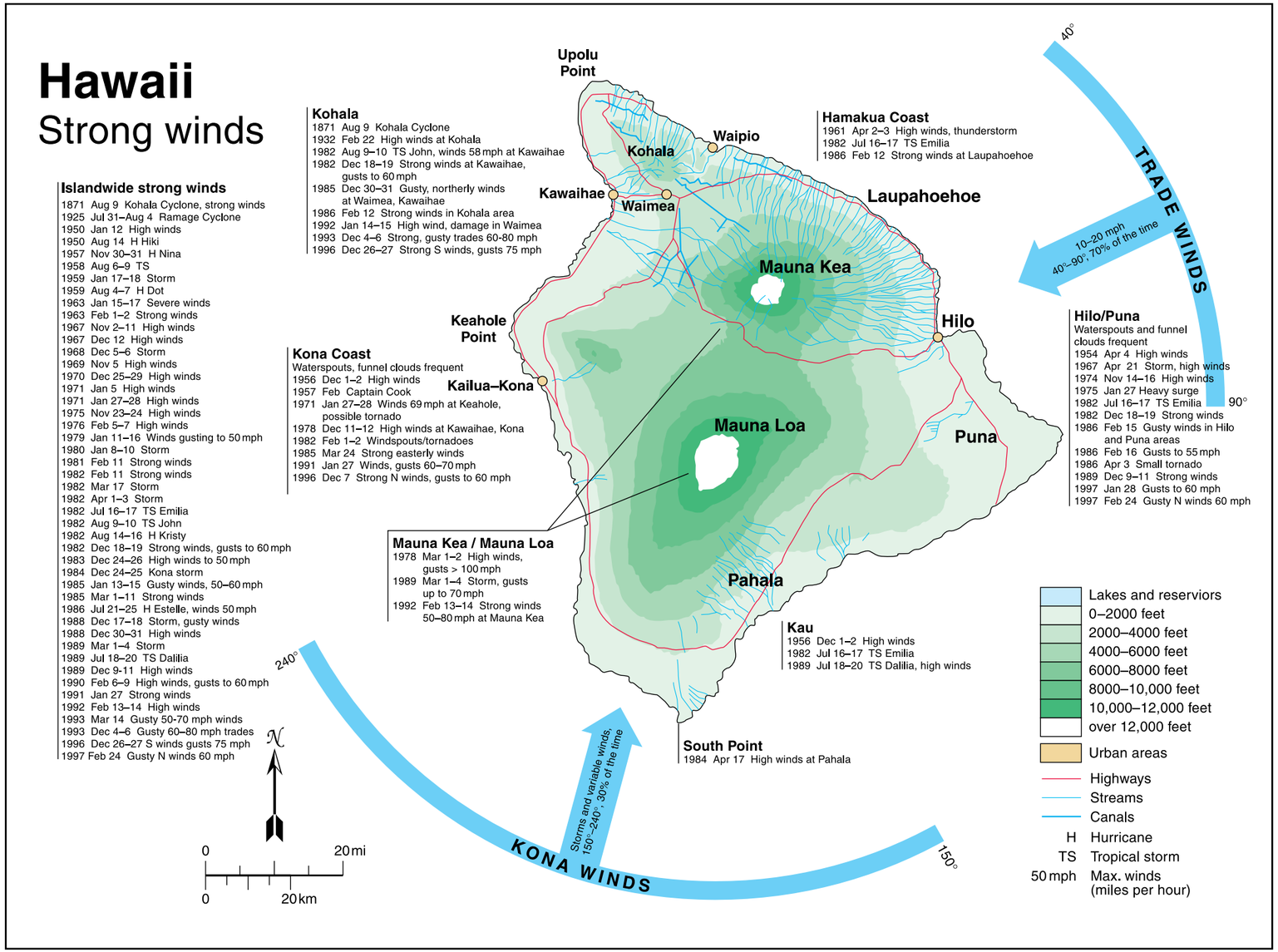
High waves

Hawaii's shorelines receive high waves that are generated by distant storms in the Northern and Southern Hemisphere and by tropical storms, hurricanes, and Kona storms that enter Hawaiian waters. Annual high waves arrive from north swell in the winter and range between 10 and 20 ft, while waves from south swell during summer generally do not exceed 4-6 ft. Occasional extreme wave events, however, do occur, such as the enormous north swells of February 1993 and January 1998 that brought 20-30 ft waves to the north facing shores. Infrequent but significant south swells also occur, such as the July 1986 swell and the King Kamehameha Day swell of June 25-30, 1995, that produced 8-12 ft surf along southern shores. High waves of 6-8 ft can be produced by well-developed trade wind swell, but usually trade wind waves are 2-4 ft. While it is Kona storms in winter that produce occasionally damaging waves ranging 4-6 ft along south and southwest shores, it is tropical storms and hurricanes during summer and fall that bring damaging high waves of 10-30 ft several times each decade to any and all shorelines in Hawaii.

Records of high wave events and waves from hurricanes or tropical storms date back to the late 1800s, but the majority of wave data reflect only the last 45-50 yr. During this time period, high waves along the north and northeast shore due to north swell have commonly reached heights of 20-30 ft, and overwash of the Hilo breakwater and flooding of the coastal roads near Hilo, caused damage in November 1996 and January 1998. High waves along the south shore of Hawaii have been damaging to isolated areas between Kailua-Kona and Kawaihae. Alii Drive in Kailua town is located particularly close to the ocean in many places, and suffers periodic overwash. Power and telecommunications lines are threatened during large wave-induced erosion events such as the King Kamehameha Day swell of June 1995.



Hawaii
Strong winds



Strong winds

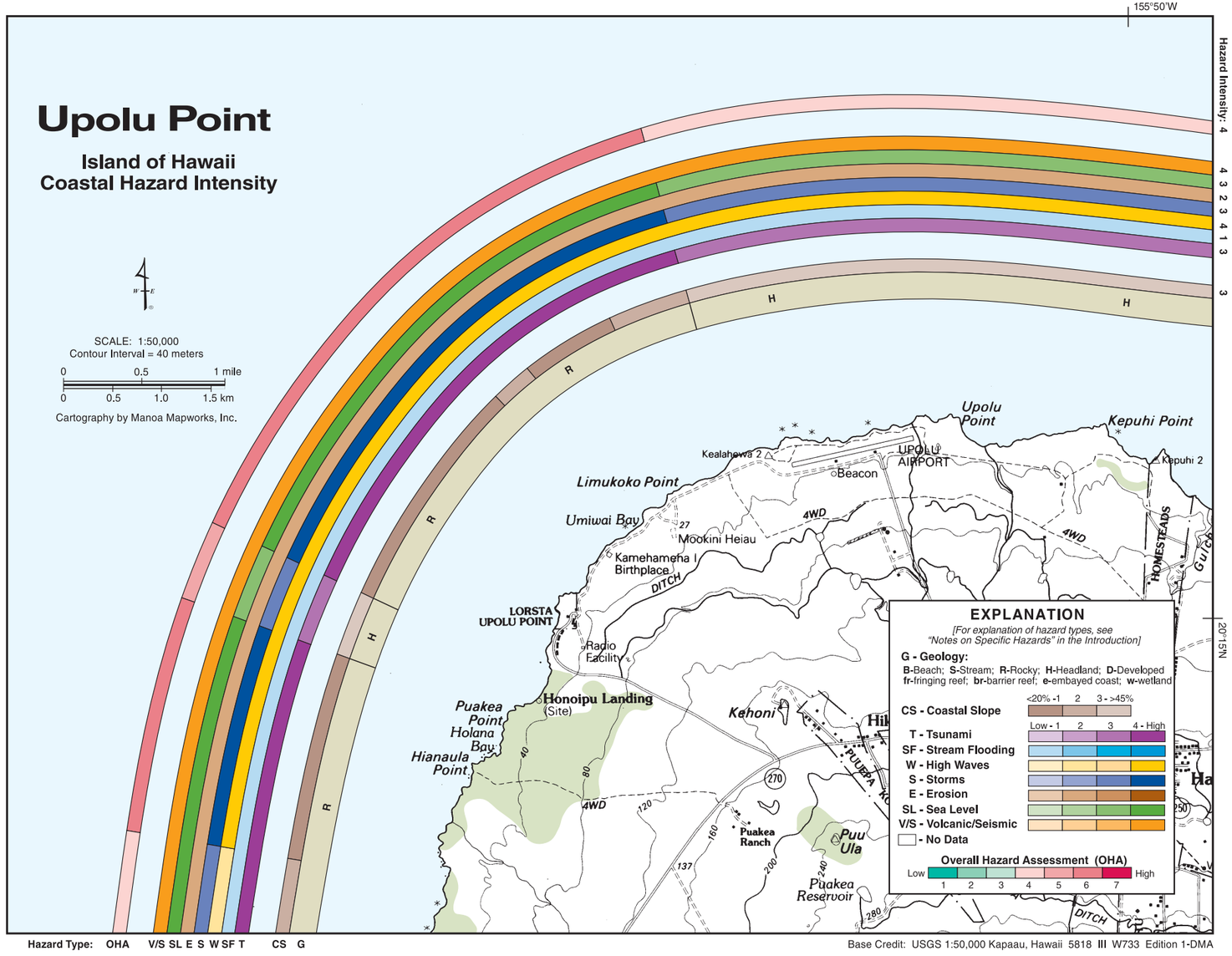
The dominant winds on the Big Island of Hawaii include trade winds, Kona winds, and winds associated with hurricanes and tropical storms. Northeast trade winds prevail most (70%) of the year and generally blow 10-20 mph. Exceptionally strong and gusty trade winds occur when the sub-tropical high of the central North Pacific Ocean intensifies. These can reach 40-60 mph in the coastal zone of Hawaii, sometimes for several days at a time. High winds associated with Kona storms tend to approach from the south and southwest as winter storms travel through Hawaiian waters and can reach greater than 50 mph. The highest and most damaging winds are most commonly associated with passing tropical cyclones (hurricanes, tropical storms, and tropical depressions). Most tropical storms approach the islands from the southeast and pass to the west, just south of the Big Island. As a result, the southeast coast of the Big Island has been subject to numerous high wind and wave events due to passing storms. Occasionally, tropical storms track east of the islands and the north-facing coast of the Big Island is impacted. An important consequence resulting from the extremely high relief on the Big Island is the acceleration of winds as they descend from the higher elevations to the coastal zones below. Localized microbursts and downdrafts often occur on the downwind side of the steep mountains. As a result, the highest wind speeds are commonly found on the side of the island opposite the approach of storms and high wind events.

Even though the Big Island has not sustained a direct hit by a hurricane strength storm, several strong tropical storms have brought about considerable damage. Since 1871, 56 high wind events have affected the entire island. Many of these were associated with passing hurricanes and tropical storms. Most recently, Hurricane Estelle, in July of 1986, created winds of 50 mph and demolished 5 homes along the southeast coast. Other strong events include Hurricanes Dot and Nina in 1959 and 1957, respectively, and tropical storm Dora in 1993. Intense trade wind events with maximum velocities of 60-80 mph, like in December of 1993, have been reported on all sides of the island. High Kona storm winds have been recorded with hurricane strength speeds, such as in December 1996, along the Kohala coast near Kawaihae. In addition to high winds in winter from Kona storms, tornadoes were reported along the Kona Coast in February 1982 and January 1971, as well as along the Hilo and Puna coast in April 1986.

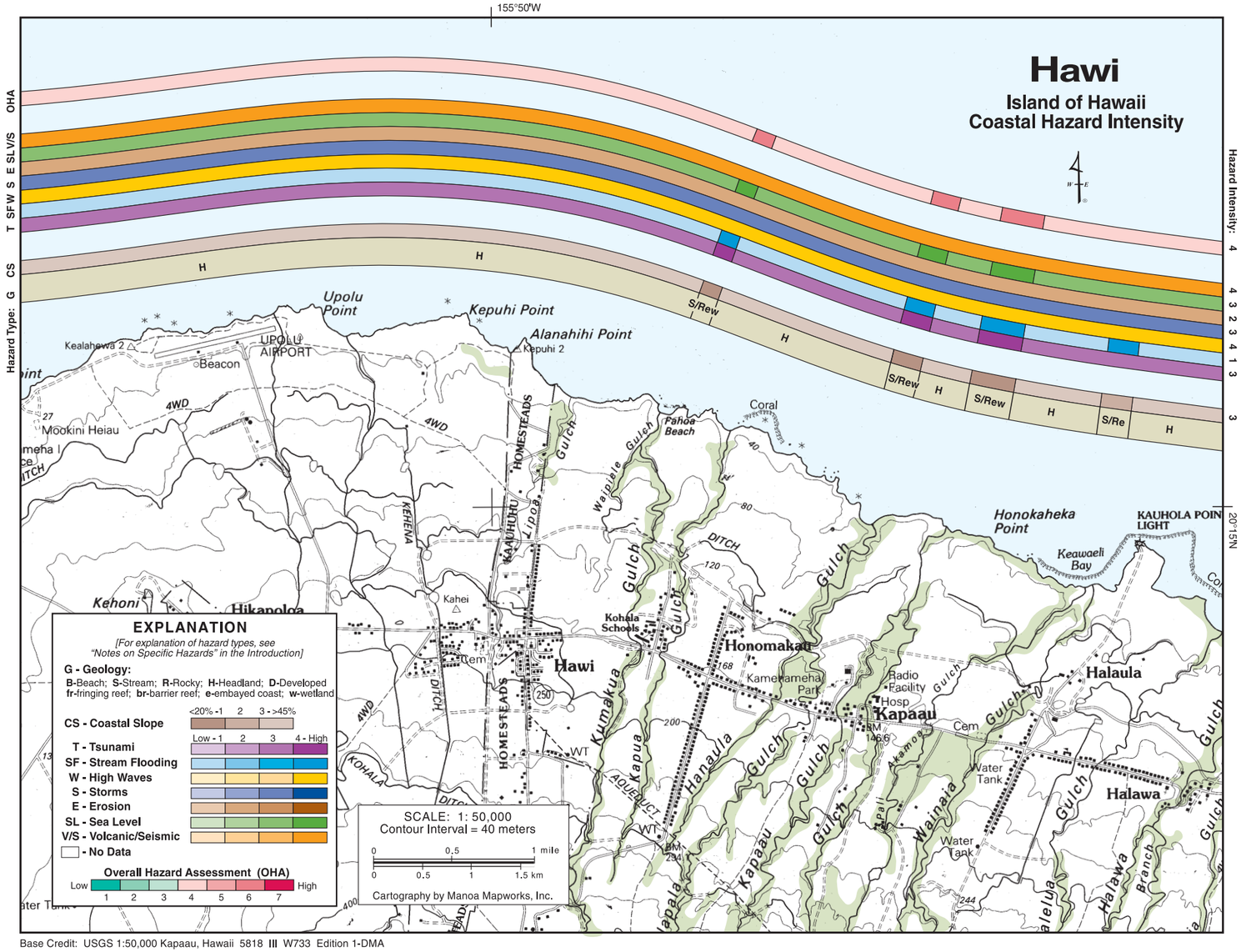
Upolu Point

The rocky headlands of Upolu Point border the northern most shores of the Island of Hawaii. The coast slopes gently between Hianaula and Limukoko Points but becomes steeper and nearly inaccessible to the east toward Kepuhi Point. Numerous small rocky embayments separate these promontories. Sandy beaches do not exist, but boulder beaches attest to the extreme wave energy that shapes this coast. High waves from north swell in winter, ranging 10-20 ft, and moderately high trade wind waves throughout the year make Upolu's north-facing coastline a high energy coast. Despite low rainfall, several streams cut across the coastal plain transporting runoff and terrigenous sediments from the upper reaches of Kohala Volcano. The Upolu coast is relatively undeveloped except for the Upolu Airport and several heiau (temple) and historical monuments. Coral reefs are nearly absent, except for small patch reefs and isolated coral colonies in the lee of headland promintories where they are protected from high wave energy.

The Overall Hazard Assessment (OHA) for Upolu largely reflects the variation in coastal slope and aspect, which controls hazards associated with flooding and high waves. The OHA is high (6) from just south of Hianaula Point to Kealahewa except for Puakea Point where it is moderate to high (5). Along this northwest-facing, low-lying coast, the threat of tsunami, high waves, storms, and sea-level rise is high, except at the Puakea Point headland where the tsunami, storms, and sea-level rise hazards are reduced to moderately high because of the steeper slope along that headland. Stream flooding and erosion are low and moderately low, respectively. The volcanic/seismic threat for Upolu (Zone 9; Table 10, p. 24) is high, as it is along the entire coastline of the Island of Hawaii. In the southwestern portion of Upolu the OHA is moderate (4), where the high waves threat is moderately high and the storm hazard is moderately low. Along the steep slopes east of Kealahewa, the OHA is moderate (4) where the tsunami, storm, and sea-level rise hazards are reduced to moderately high.



Upolu Point at the wind-swept northwest corner of Hawaii is formed of gently-sloping lava flows from Kohala Volcano that meet the sea as 10-30 ft rocky cliffs.



Base Credit: USGS 1:50,000 Kapaau, Hawaii 5818 III W733 Edition 1-DMA

Hawi

The Hawi coast is comprised of steep rocky headlands separated by numerous small embayments at the Kumakua, Hanaula, Kapaau, and Wainaia stream mouths. Wetlands have formed in the first three of these embayments where the streams deposit terrigenous sediments quarried from the deeply incised valleys above. Wave energy is high along this coast most of the year, which helps to disperse the soil and silt that is delivered from the streams. Even so, it is common to see plumes of brown sediment-rich water hugging the coast, especially after high rainfall. Despite the high sediment discharge into the nearshore zone, coral reefs become increasingly common east of Pahoa Beach. Development is low along the Hawi coast due to its difficult access. The region is relatively arid and experiences persistent trade winds.

The Overall Hazard Assessment (OHA) is moderate (4) along the steep rocky coastal cliffs and high (6) at the low-lying Kumakua, Hanaula, and Kapaau stream mouths. The OHA in these coastal embayments is ranked high because the tsunami, stream flooding, high waves, and sea-level threats are high, storms are only moderately high, and erosion is moderately low. In Keawaeli Bay, stream flooding is high and the sea-level hazard there is moderately high. Along the intervening steep coastal cliffs, the tsunami and sea-level hazards are moderately high, and stream flooding is low. The Hawi coast lies in lava flow hazard zone 9 (Table 10, p. 24). The volcanic/seismic hazard is high along this coast due to its proximity to high seismic activity associated with volcanic eruptions at Kilauea Volcano to the south.

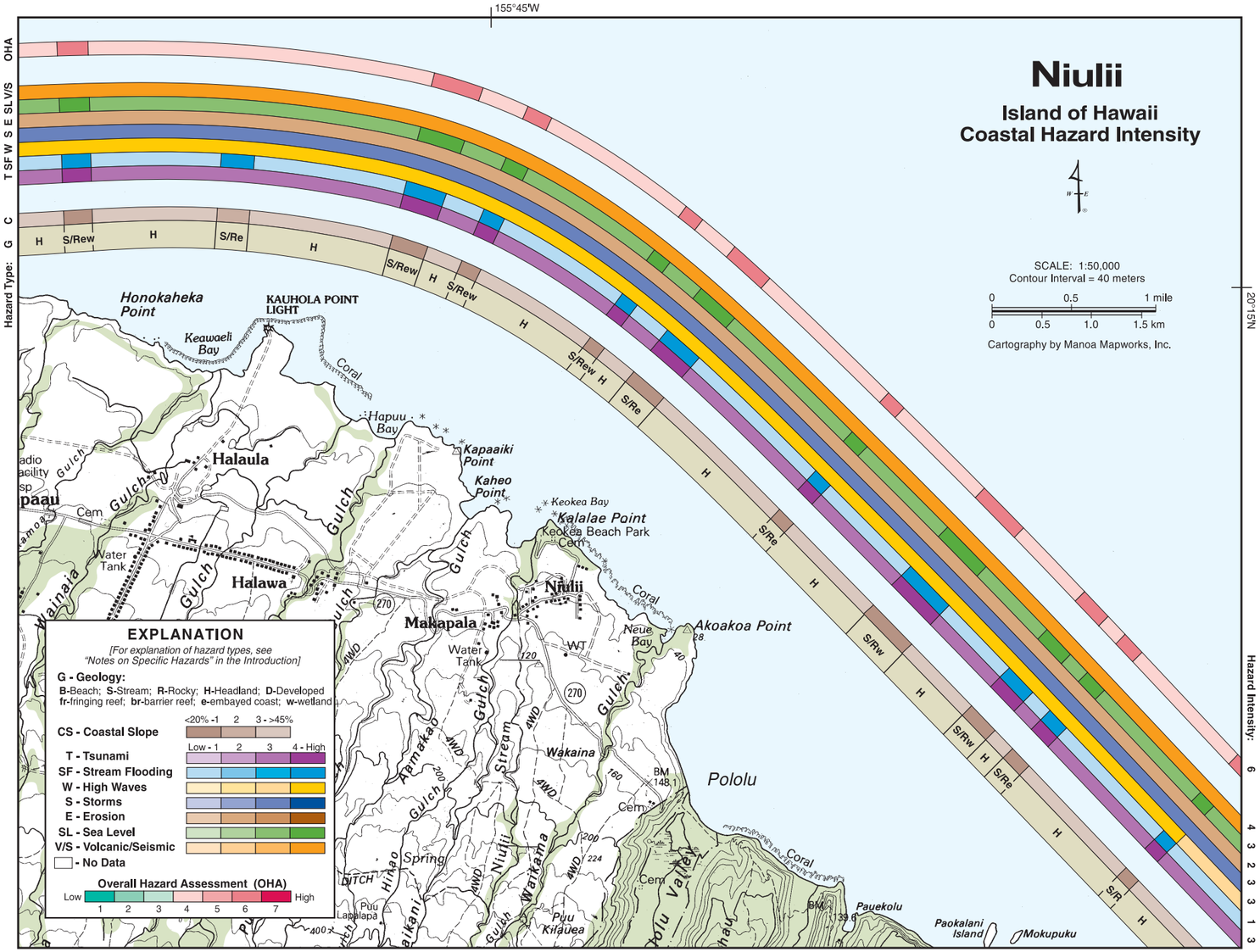
Deeply incised gulches, like Kumakua Gulch (shown here), are common along the Hawi coast, where steep 15 to 60 ft sea cliffs plunge into rough waters of North Kohala.

Niulii

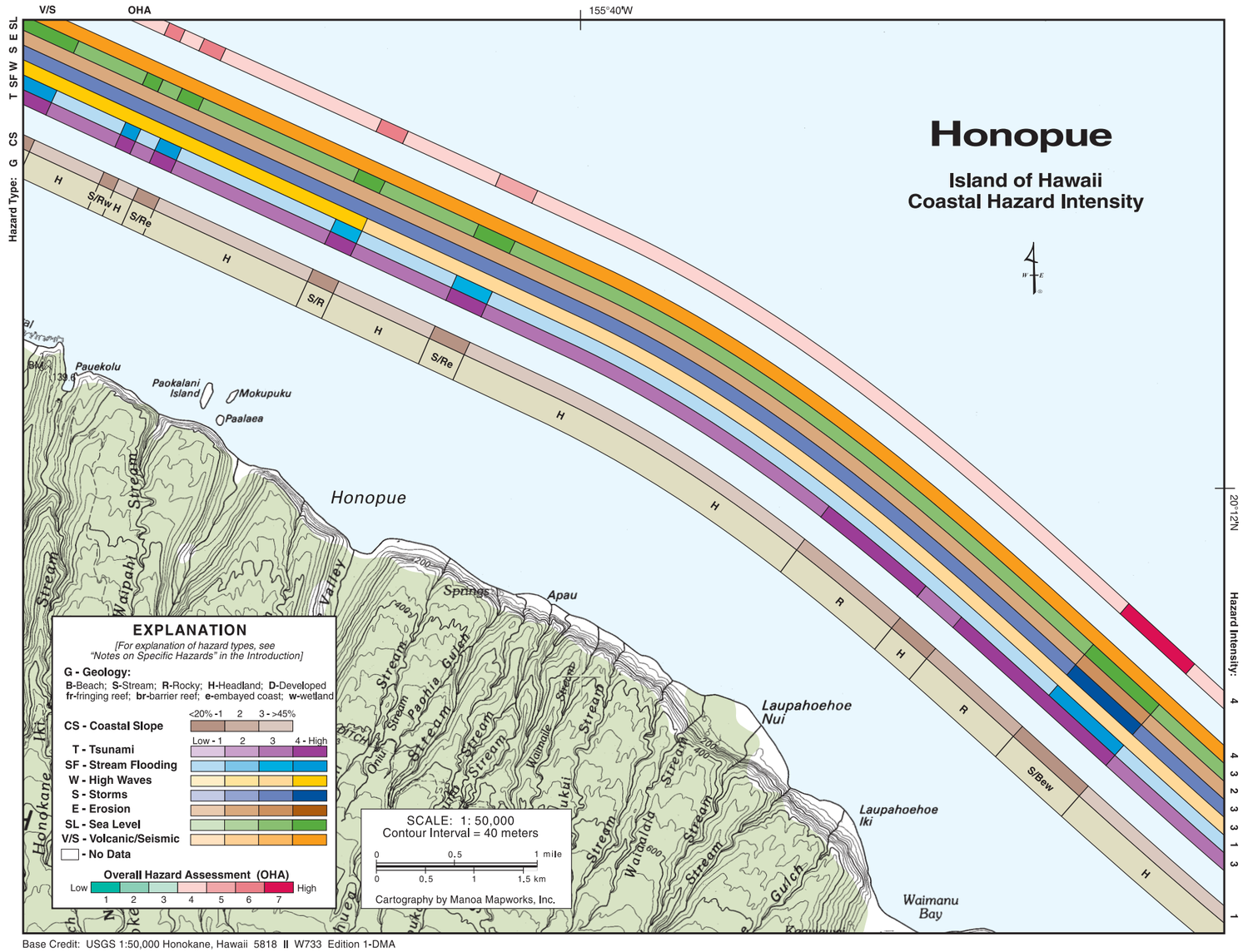
Between Keawaeli Bay and Pauekolu in Pololu Valley, the Niulii coast is steep with rocky headlands surrounding irregular low-lying rocky embayments at stream mouths. The highest tsunami runup ever recorded in Hawaii occurred in 1946 near Kalalae Point, where it was measured at 55 ft against the coastal cliffs. Small wetlands have formed in many of the embayments where stream-deposited sediments accumulate. High waves and persistent trade winds erode this rocky coast, leaving small rocky sea stacks abandoned offshore of the retreating sea cliffs. A few boulder beaches, such as at Keokea Beach Park, also occur along this coast. The beach along Pololu to the south is comprised largely of black sand. Pololu Valley is the northernmost of seven deeply incised amphitheater-shaped valleys along the northeast coast of Hawaii. Pololu is only slightly developed, although it once flourished with taro agriculture. Well-developed fringing reefs occur at Kauhola Point and seaward of the town of Niulii. Access along the coast south of Pololu Valley is limited to foot trail and boat, as the coastal road ends at a lookout situated on the north ridge overlooking Pololu Valley.

The Overall Hazard Assessment (OHA) for the low-lying coastal embayments and stream mouths along the Niulii coast is high (6) while for the steep rocky headlands it is moderate (4). In each of the low-lying coastal embayments, except Keawaeli Bay, which is steeper and where the tsunami threat is moderately high, the tsunami, stream flooding, high waves, sea-level, and volcanic/seismic hazards are high. In between the embayments, where the coastal headlands are steep, the tsunami and sea-level hazards are moderately high, and stream flooding is low. The hazard due to high waves along this entire coast is high, while that due to storms is moderately high. Erosion is moderately low. Niulu lies in lava flow hazard zone 9 (Table 10, p. 24). The volcanic/seismic threat is high along the Niulu coast as it is for the entire coast of the Big Island due to active volcanism and seismicity associated with eruptions of Kilauea.

Beyond the Pololu Valley Lookout at Akoakoa Point (foreground), the Niulii coast becomes increasingly steeper and access is only afforded by boat and/or footpath.



Base Credit: USGS 1:50,000 Kapaau, Hawaii 5818 III W733 Edition 1-DMA and USGS 1:50,000 Honokane, Hawaii 5818 II W733 Edition 1-DMA



Base Credit: USGS 1:50,000 Honokane, Hawaii 5818 II W733 Edition 1-DMA

Honopue

Deep stream valleys cut into spectacular sea cliffs ranging 500-1000 ft high along the Honopue coast. Two relatively low-lying coastal plains between Apau and Laupahoehoe Nui and at Laupahoehoe Iki have formed along the rocky coast. The Honopue region of the Kohala coast receives only moderate rainfall, but active streams bring considerable volumes of sediment to the coastal plains and waters of the embayments. In times past, this sediment on the valley floors provided rich soil for taro farming, however, severe flooding made it difficult to maintain the farms. Access to the beautiful amphitheater valleys is limited to foot trail and boat. Black sand beaches are common at the shoreline of these valleys. Three small islands stand against the relentless attack of high waves and trade winds just offshore and south of Pauekolu. Coral reefs occur in the northern portion of the area, but are less common in the south.

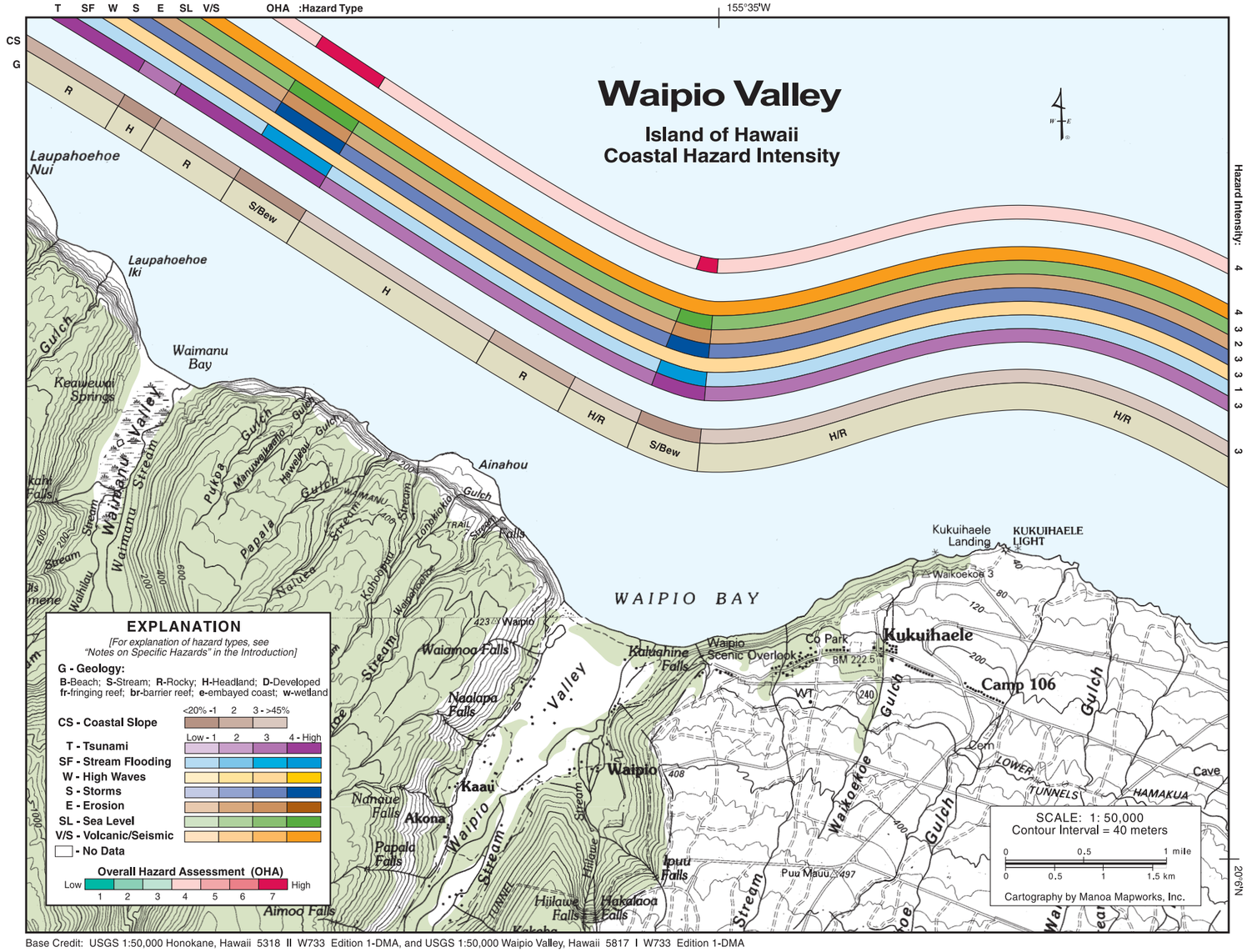
The Overall Hazard Assessment (OHA) for Honopue is moderate (4) along the steep rocky cliffs and high (6) at the small coastal embayments northwest of Apau. This difference is largely due to the high tsunami, stream flooding, and sea-level hazards within these bays. The storm threat is moderately high, erosion is moderately low, and the volcanic/seismic threat is high along the entire Honopue coast because of active seismicity associated with volcanic eruptions at Kilauea. The Honopue coast is located in lava flow hazard zone 9 (Table 10, p. 24). The hazard from high waves northwest of Mokupuku and Paalaea Islands is reduced to moderately high to the southeast, where waves associated with large north and northwest swell refract and lose energy by the time they reach the shoreline. The tsunami hazard is high along the two relatively low-lying coastal plains between Apau and Laupahoehoe Nui and at Laupahoehoe Iki.

Gulleys and clean unvegetated scarps with remnant islands and sediment-laden waters offshore attest to active erosion along the steep, rocky Honopue cliffs.

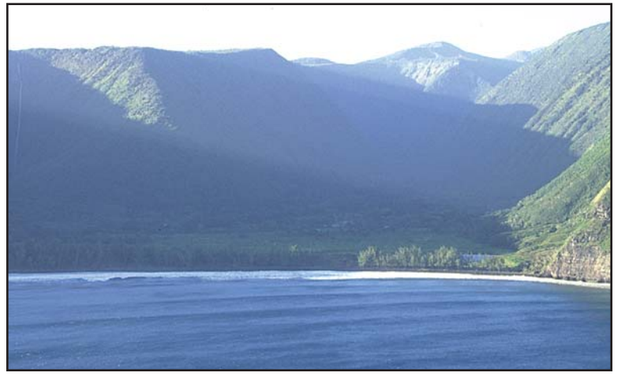
Waipio Valley

The Waipio coast abruptly changes at Waipio Bay from one dominated by steep sea cliffs and deeply incised valleys of the older Kohala volcano to a more gently sloping and younger coastline to the south. Waimanu and Waipio Valleys are famous for their scenic splendor and isolation. They were extensively developed for taro agriculture in the past but have been almost entirely abandoned due to severe flooding and tsunami inundation this century, as well as to difficult access. Today only Waipio Valley is still partly cultivated. The seaward edges of the valley floors are mostly wetlands. Access to Waipio Valley can be achieved by 4-wheel drive vehicle from Kukuihaele, but beyond this point the coast is accessible only by foot trail or boat. Wide and extensive black sand beaches occur at both Waimanu and Waipio Bays. To the south, the coast is mostly rocky except for an ephemeral small beach at Kukuihaele Landing. Coral reefs are very sparse and only exist as small isolated patch reefs.

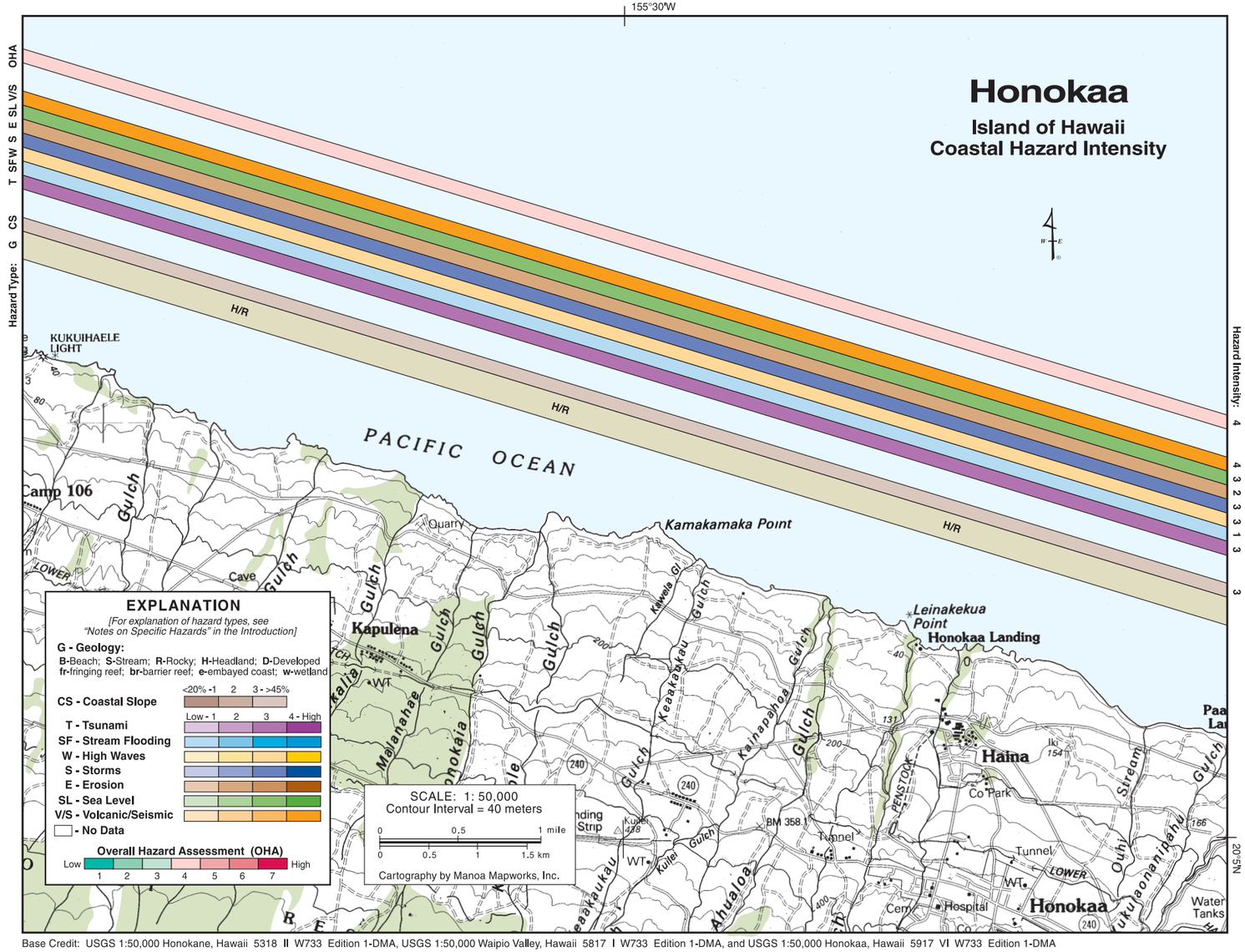
The Overall Hazard Assessment (OHA) within Waipio and Waimanu Bays is very high (7), while along the surrounding steep rocky sea cliffs it is moderate (4). At the low-lying coastal embayments of Waipio and Waimanu the tsunami, stream flooding, storm, sea level, and erosion hazards are moderately high. These bays generally receive moderately high waves. Along the steep sea cliffs the tsunami, storm, and sea-level hazards are moderately high, while erosion is moderately low and stream flooding is low. The high wave hazard is moderately high along the steep rocky cliffs. The steeper coast north of Waipio is in lava flow hazard zone 9 while the more gradually sloping coast to the south is in lava flow hazard zone 8 (Table 10, p. 24). The volcanic/seismic threat is uniformly high throughout the entire Waipio Valley coast due to active seismicity associated with volcanism at Kilauea.



Base Credit: USGS 1:50,000 Honokane, Hawaii 5318 II W733 Edition 1-DMA, and USGS 1:50,000 Waipio Valley, Hawaii 5817 I W733 Edition 1-DMA



Waipio Valley is characteristic of a youthful valley with its deeply incised "V-shaped" sides. Considerable sedimentation along the valley floors has established an extensive floodplain, which has been fruitfully cultivated throughout the past but is also highly susceptible to flooding by both heavy rainfall and marine overwash.



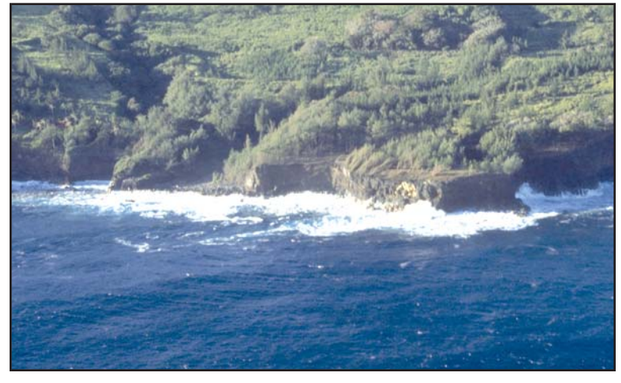
Base Credit: USGS 1:50,000 Honokane, Hawaii 5318 II W733 Edition 1-DMA, USGS 1:50,000 Waipio Valley, Hawaii 5817 I W733 Edition 1-DMA, and USGS 1:50,000 Honokaa, Hawaii 5917 VI W733 Edition 1-DMA

Honokaa

The rocky Honokaa coast between Kukuihaele Point and Honokaa Landing is relatively steep with 80-100 ft high cliffs fronting the sea. Portions of the coast are slightly embayed. There are no unconsolidated sand beaches, only rocky platforms and boulders at the base of the coastal scarps. Trails lead down the steep cliffs from the bluffs, which are moderately developed with private residences. Numerous gulches cut across the coastal plain, draining the east-facing slopes of Mauna Kea above. Although relatively arid, rainfall is periodically intense and landslides along the steep cliffs occur. Facing northeast, the Honokaa coast receives the direct approach of the trade winds and trade-wind swell, as well as refraction of north swell. Reflection of waves off the rocky cliffs creates very turbulent seas just offshore. Little coral grows along this coast.

The Overall Hazard Assessment (OHA) is uniformly moderate (4) along the entire Honokaa Coast because of the consistent rocky substrate and largely unchanging coastal slope. The tsunami hazard is moderately high along these relatively steep slopes. Stream flooding is low due to the relatively steep coast. The high waves and storm hazards are moderately high, while erosion is moderately low due to the rocky substrate. The sea-level threat is moderately high where the island is subsiding and sea level is rising. Honokaa lies in lava flow hazard zone 8 (Table 10, p. 24). The volcanic/seismic threat is high along the Honokaa coast as it is along the entire coast of the Island of Hawaii due to high seismic activity and volcanism associated with the eruption of Kilauea.

South of Waimanu and Waipio, the cliffs of the Hamakua coast near Honokaa become more gently sloping and range between 10 and 30 ft high.

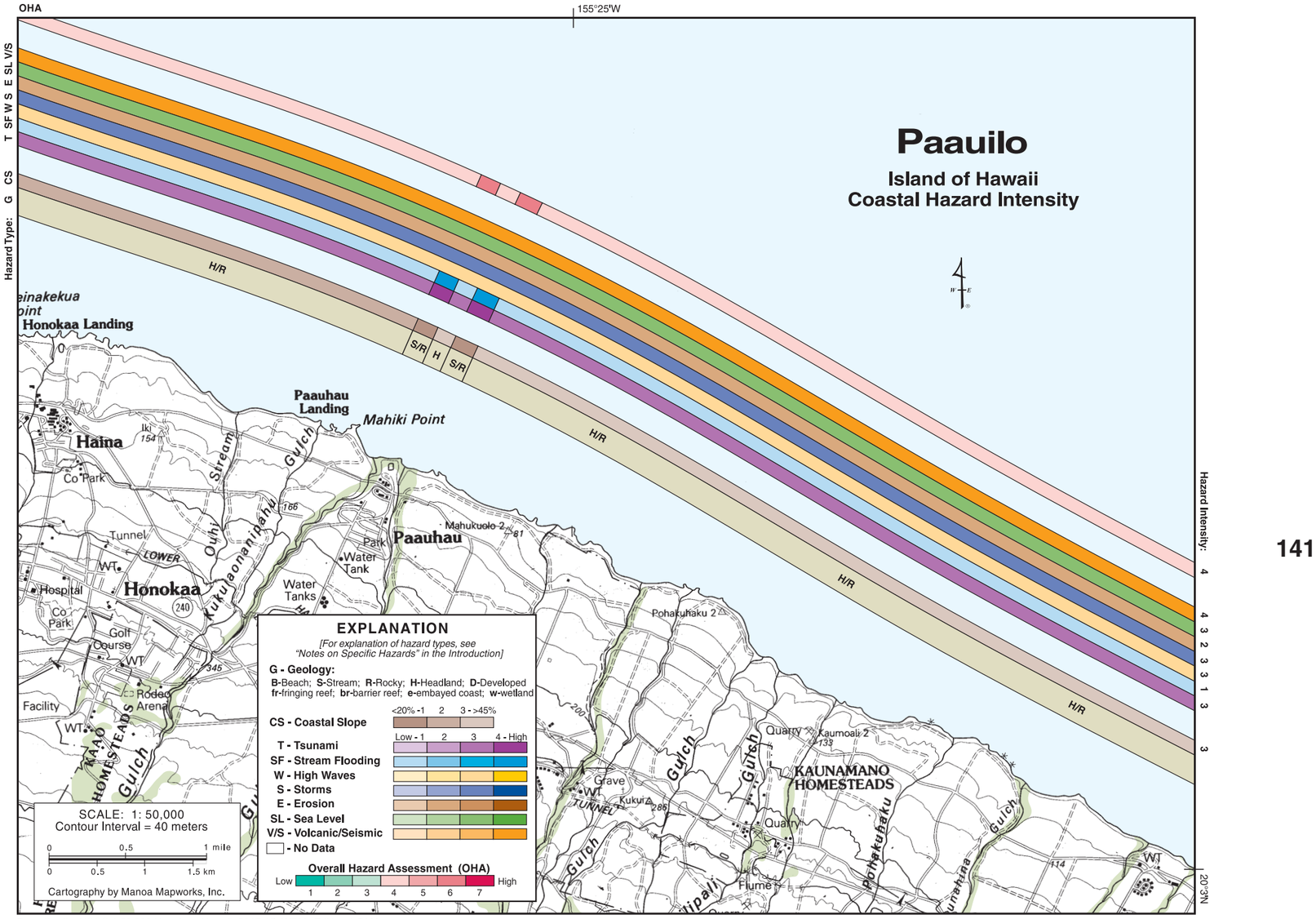


Paauilo

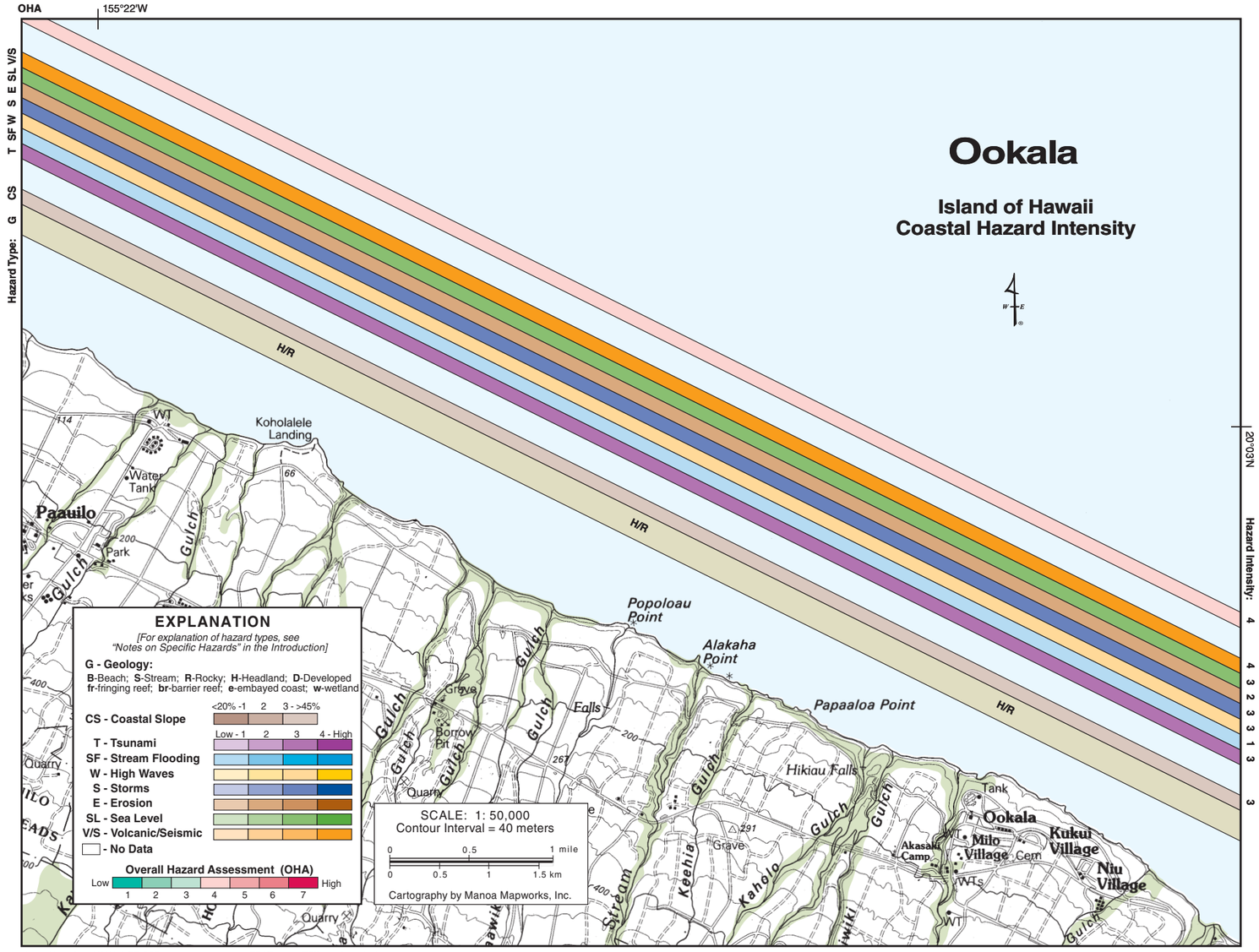
Between Honokaa Landing and Kaunamano Homesteads the coastal slope of the Paauilo region becomes increasingly more gradual despite the sea cliffs that line the entire coast. Access by auto is limited to Paauhau Landing and neighboring hillsides, otherwise one must travel by foot trail or boat to reach the coastline. The headlands are generally rocky, but in some locations soils have developed sufficiently that, when saturated with rainfall, slope failures and landslides occur. Streams draining Mauna Kea Volcano have deeply incised the coastal slopes, creating narrow gorges and waterfalls. The same streams also transport large amounts of terrigenous sediments to the coastal zone, often clouding the nearshore waters with silt after heavy rains. Many small rock outcrops line the coast, but few coral reefs have taken hold.

The Overall Hazard Assessment (OHA) for the Paauilo Coast is moderate (4) except at the two stream mouths that form low-lying coastal embayments at Paauhau, where the OHA is high (6). Tsunami is moderately high throughout the region, except at the Paauhau stream mouths, where it is high. Stream flooding is low along the Paauilo coast, except at the Paauhau stream mouths, where it is high. High waves, storms, and the sea-level threat are moderately high along the entire coast, while erosion is moderately low. The Paauilo region is located in lava flow hazard zone 8 (Table 10, p. 24). The volcanic/seismic hazard is high along the Paauilo coast due to its proximity to Kilauea which is the primary source region for active seismicity and volcanism affecting the Big Island.

Nearshore turbulence is common along the Paauilo coast where persistent waves from trade winds and winter north swell abruptly meet the rocky 15 to 60 ft cliffs. In addition, runoff from heavy rains and agricultural practices may lead to sedimentation in the coastal zone.



Base Credit: USGS 1:50,000 Honokaa, Hawaii 5917 VI W733 Edition 1-DMA



Base Credit: USGS 1:50,000 Honokaa, Hawaii 5917 IV W733 Edition 1-DMA

Ookala

The slopes of Mauna Kea Volcano steepen near the town of Ookala and the entire coast between Koholalele Landing and Niu Village is lined by steep sea cliffs ranging 50-300 ft high. Only a few foot trails enable access to the shoreline from the headland bluffs above. Many private developments, including residences and small businesses, have been constructed on the bluffs overlooking the sea. Periodically the cliffs become saturated with heavy rainfall and may develop landslides. Several streams cut across the Ookala coastal plain creating deep gulches, beautiful waterfalls, and boulder beaches at their terminus. This region receives moderate to high wave energy from north swell and trade wind waves, limiting reef development.

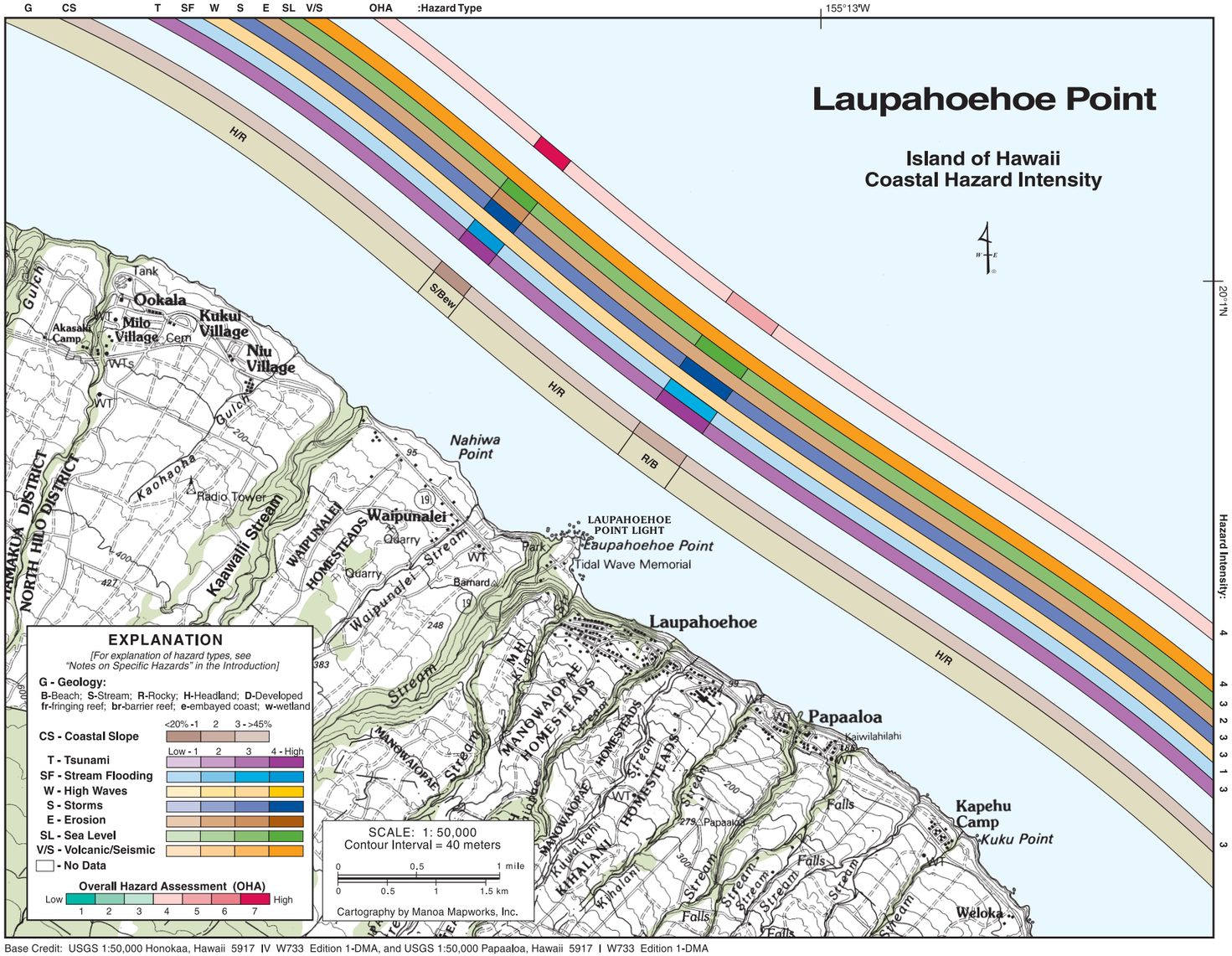
The Overall Hazard Assessment (OHA) is moderate (4) along the Ookala Coast. This ranking reflects a uniform assessment of the individual hazards due to the relatively unchanging coastal slopes and geology. Tsunami is moderately high. Stream flooding is low due to the moderate rainfall and relatively steep coastal slope. The hazards from high waves and storms are moderately high. While erosion is moderately low due to the hard rocky substrate, the sea-level hazard is moderately high because the island is sinking in addition to experiencing global sea-level rise. Ookala is within lava flow hazard zone 8 (Table 10, p. 24). The volcanic/seismic threat is high along the Ookala coast which receives episodic seismic activity associated with volcanism at Kilauea.

Steep headlands formed by active headwall erosion from wave scour and hillslope failure characterize much of the Ookala coast.

Laupahoehoe Point

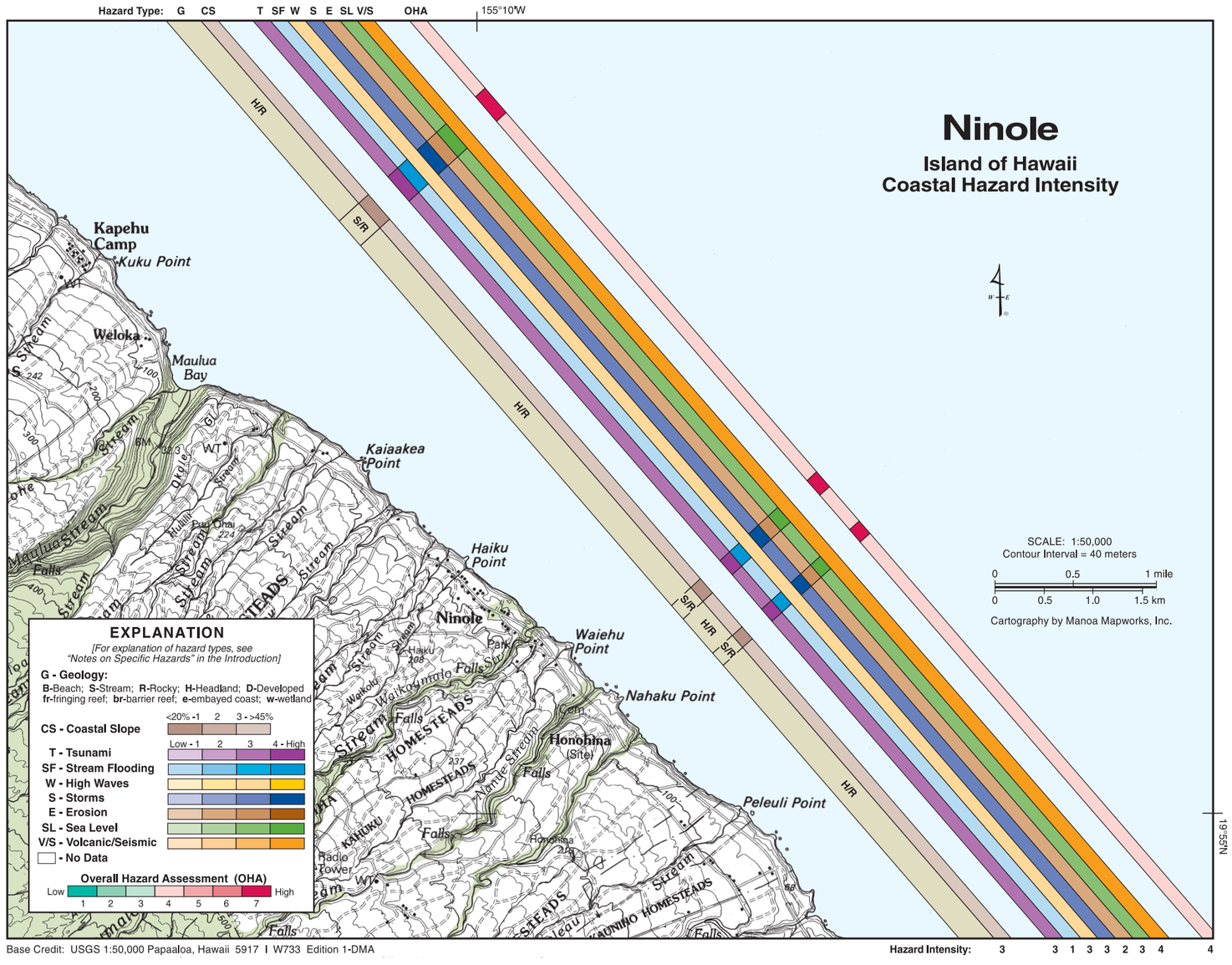
Steep coastal cliffs comprised of late stage Mauna Kea volcanics border the entire Laupahoehoe shoreline. A small rocky pebble beach exists at Laupahoehoe Point Park and at the Kaawalii Stream mouth located between Niu Village and Nahiwa Point. Laupahoehoe Point is the site of the Tidal Wave Memorial, placed there in memory of the 20-ft tsunami wave that destroyed the elementary school situated on the point and took the lives of a number of teachers and students on April 1, 1946. Only very small embayments occur along the cliffed coast where streams meet the sea, and they are difficult to reach by foot. High waves continuously assault this coastline making ocean access difficult. This region receives significant rainfall throughout the year, that often contributes to landslides along the cliff faces. Even so, development, focused between Ookala and Niu Village north of Laupahoehoe Point and between Laupahoehoe town and Papaaloa to the south, continues to creep ever closer to the cliff edges. There is no significant coral reef growth along this turbulent coast, a result of the high waves and terrigenous sediment input to the nearshore zone.

The Overall Hazard Assessment (OHA) is mostly moderate (4) along the steep cliffed Laupahoehoe coast. Even though this northeast-facing coast receives intense wave and wind energy the steep cliffs along the majority of the coast help to mitigate against flooding, marine overwash, erosion, and inundation associated with sea-level rise. As a result the hazards due to tsunami, high waves, storms, and sea-level rise are ranked moderate to high. Stream flooding and erosion are ranked low and moderate to low, respectively. At the low-lying Kaawalii Stream mouth, where the tsunami, stream flooding, storm, erosion and sea-level rise hazards are higher than the surrounding cliffed coasts, the OHA is ranked very high (7). In addition, at Laupahoehoe Point, where the Laupahoehoe and Kilau Streams empty into the sea, the OHA is high (6) reflecting higher tsunami, stream flooding, storm, erosion, and sea-level rise hazards at the low-lying beach park area. Laupahoehoe lies within lava flow hazard zone 8 (Table 10, p. 24).Volcanism and seismicity is high for the entire Hawaii coastline due to active seismicity associated with the eruption of Kilauea Volcano.



Base Credit: USGS 1:50,000 Honokaa, Hawaii 5917 IV W733 Edition 1-DMA, and USGS 1:50,000 Papaaloa, Hawaii 5917 I W733 Edition 1-DMA

Surrounded by steep, rocky cliffs to the north and south, Laupahoehoe Point is the most accessible and widely visited parcel of low-lying coastline between Niu Village and Papaaloa.



Ninole

Between Kapehu Camp and Peleuli Point, the Ninole coast is lined with steep rocky headlands, except at Maulua Bay and the outflow of the Waikaumalo and Nanue streams near Nahaku Point, where it is low lying. As a result, the Ninole coast is relatively undeveloped. All infrastructure rests upon a coastal terrace at elevations ranging between 80 and 100 ft above sea level. Spectacular waterfalls are produced as runoff drains the steep hillsides landward of the gently-sloping terrace around Honohina. High waves and steep cliffs make the sea difficult to access around Ninole. Coral growth is very limited in this region.

The Overall Hazard Assessment (OHA) for the Ninole coast is similar to most of the Hamakua coastal region. In the many isolated low-lying embayments it is higher than the surrounding steep cliffed coasts. The OHA is moderate (4) along the steep cliffs of Ninole, where tsunami, high waves, storms, and sea-level rise threats are ranked moderate to high. Because of the steep slopes, stream flooding is low and erosion is moderate to low. At Maulua Bay and the outflow of the Waikaumalo and Nanue streams near Nahaku Point the OHA is ranked very high (7) due to the high ranking for tsunami, stream flooding, storms, and sea-level rise. At these embayments the erosion threat is also ranked moderate to high. The Ninole coast lies within lava flow hazard zone 8 (Table 10, p. 24). The volcanic/seismic hazard is high along the entire coast due to active seismicity associated with volcanism at Kilauea.

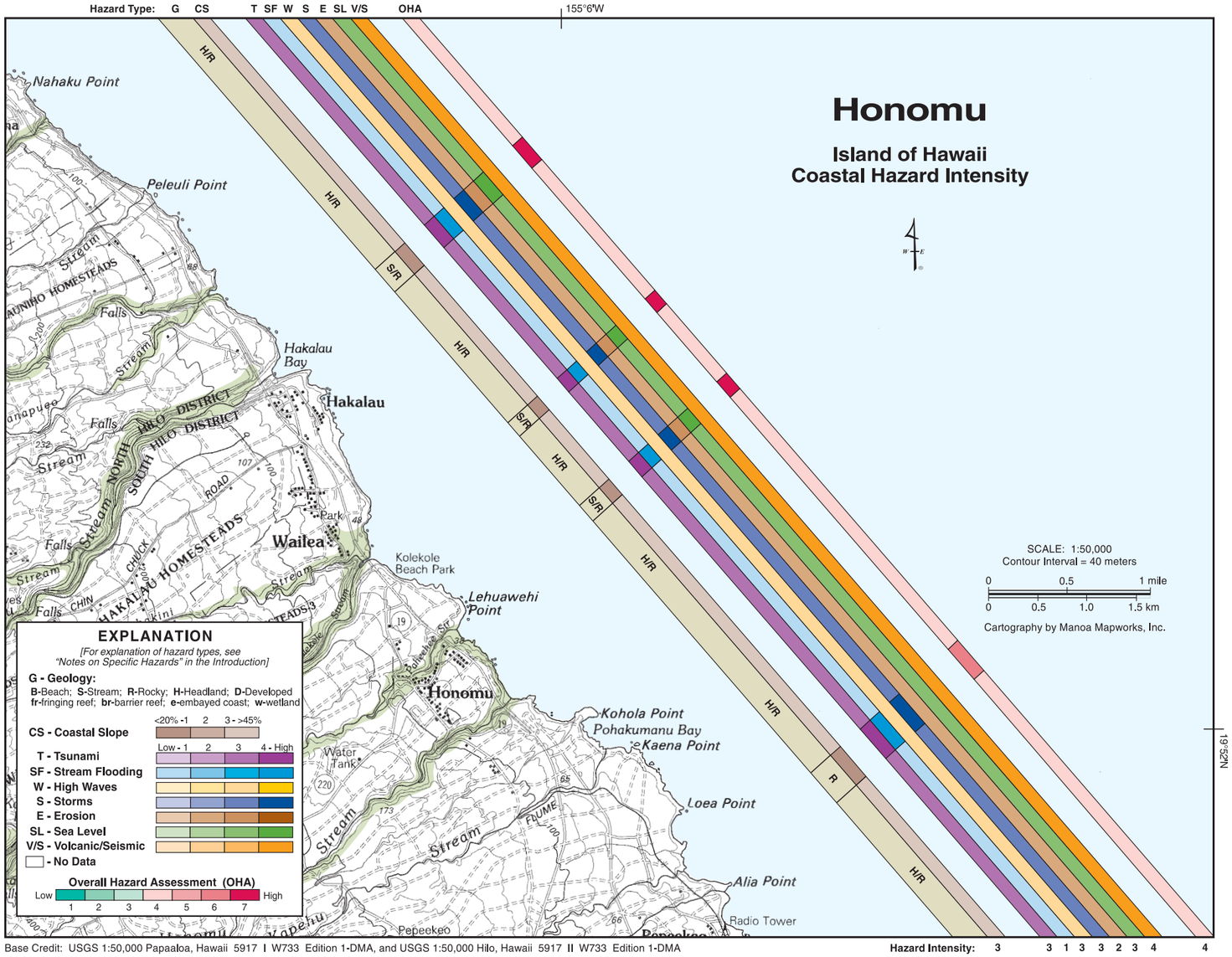
Steep sea cliffs incised by gulches and small embayments like Maulua Bay (shown here) are common along the Ninole coast.

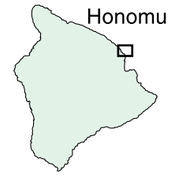
Honomu

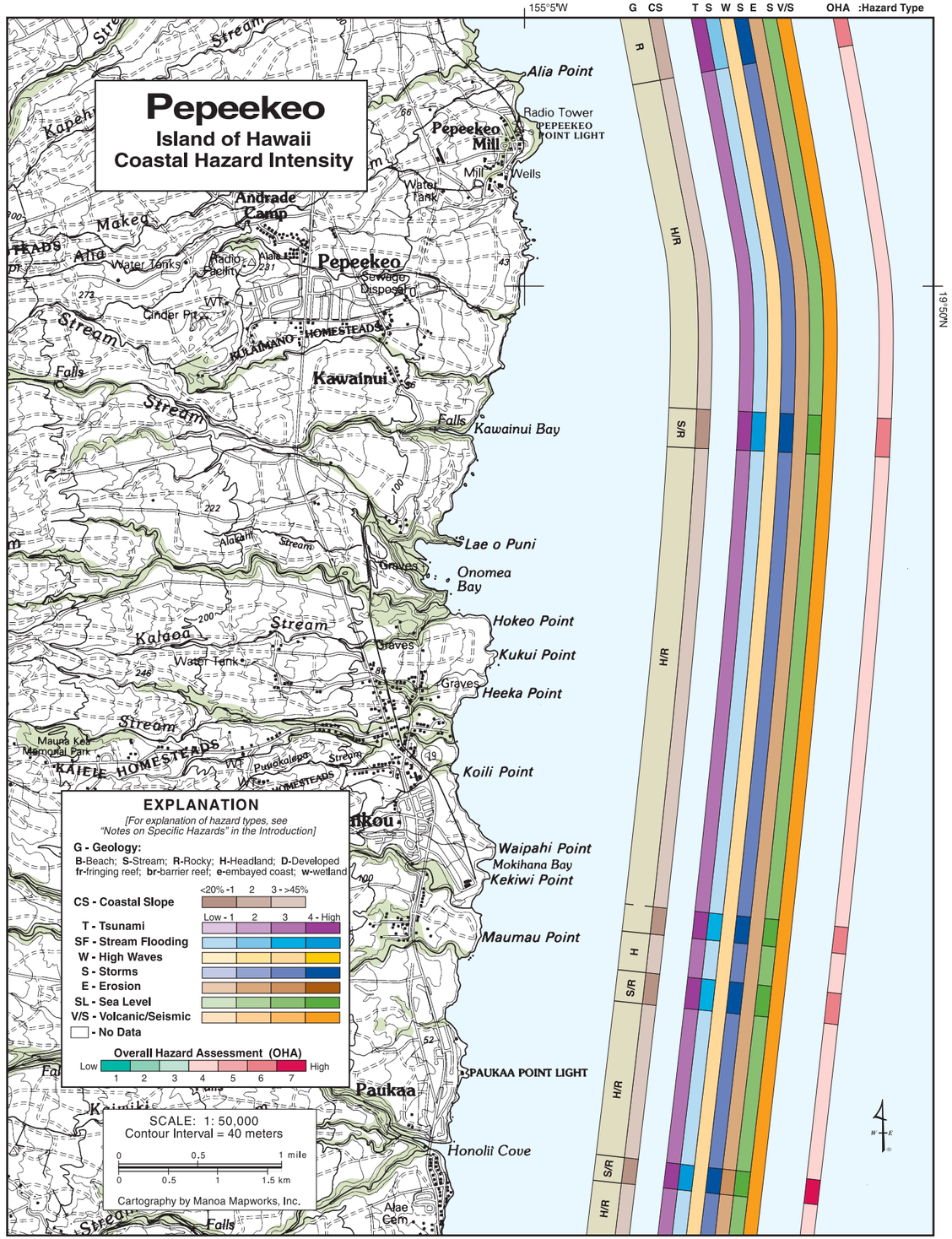
The Honomu Coast from Nahaku Point south to Alia Point is mostly a rocky headland coast with small embayments at stream mouths. The coast slopes are slightly more gentle in the southern portion of Honomu. Scenic waterfalls occur just landward of the coast. The coastal streams are important agents for transporting volcanic boulders to the stream mouths, where they become strewn along the shoreline by energetic waves that impact this coast. Small, temporary pebble and black sand beaches can occur at Hakalau Bay and Kolekole Beach Park. Heavy stream discharge into Hakalau Bay keeps the waters turbid and sediment rich. Corals are absent along this coast, while high waves and trade winds are normal.

Tsunami, high waves, and storms are ranked moderate to high along the steep-cliffed segments of the Honomu coast which faces northeast into the prevailing winds and receives significant north swell. Stream flooding is low and erosion is moderate to low where the coast is steep, whereas sea-level rise is moderate to high. The Honomu coast lies within lava flow hazard zone 8 (Table 10, p. 24) and is ranked high for volcanism and seismicity as it is along the entire Big Island coast that experiences active seismicity associated with the volcanic eruption of Kilauea. These individual rankings translate into a moderate (4) Overall Hazard Assessment (OHA) along the steep cliffs of Honomu. At the low-lying Hakalau Bay, Kolekole Beach Park, and Honomu, the OHA is elevated to very high (7) because of the increased tsunami, stream flooding, storm, erosion, and sea-level rise threats at those locations. In the embayment between Loea and Alia Points the erosion hazard is not as high as the other embayments to the north because of the rocky substrate inside the bay, therefore the OHA inside this embayment is high (6).

The Honomu coast is marked by relatively steep sea cliffs and narrow bridges spanning gulleys and small embayments.







Base Credit: USGS 1:50,000 Hilo, Hawaii 5917 II W733 Edition 1-DMA

Pepeekeo

From Alia Point south to Honolii Cove, the Pepeekeo coast is adorned with numerous rocky points that protrude seaward and shelter isolated and sometimes deeply incised coves and bays. Lae o Puni is one of these elongated rocky headlands that borders the beautiful Onomea Bay with its small rocky islets. Pebble and cobblestone beaches line the small coves within Onomea Bay and red lava rock can be seen in the cliffs along the northern side of the bay. A black pebble beach also exists at Honolii Cove, a popular surf spot along the Pepeekeo coast. Numerous streams empty into the sea along the Pepeekeo coast bringing with them significant amounts of sediment-rich waters and debris. High waves dominate this coast and help to rework the stream-transported material. Coral reefs are absent in this region. The coastal slope becomes more low-lying and gentle to the south, where development is greatest.

The variation in the hazard intensity ranking along the Pepeekeo coast primarily reflects changes in the coastal slope. Along the steep cliffs, where flooding, inundation, and marine overwash is mitigated by the high relief, the Overall Hazard Assessment (OHA) is moderate (4). Along these steep-cliffed shorelines, tsunami, high waves, storms, and sea-level rise are ranked moderately high, stream flooding is low, and erosion is moderately low. However, inside the low-lying coastal embayments of Kawainui Bay and those on either side of Maumau Point, the OHA is high (6) due to the higher tsunami, stream flooding, storm, and sea-level rise hazards. The black sand and pebble beach inside Honolii Cove is more susceptible to erosion and as a result the erosion hazard there is ranked moderately high. This translates into an OHA ranking of very high (7) for Honolii Cove. Volcanism and seismicity is high due to this region's proximity to Kilauea which is the source region for active seismicity on the Big Island. The Pepeekeo coast lies within lava flow hazard zone 8 (Table 10, p. 24).

Steep sea cliffs and rocky headlands of Mauna Kea lava flows and dikes comprise the Pepeekeo coast.

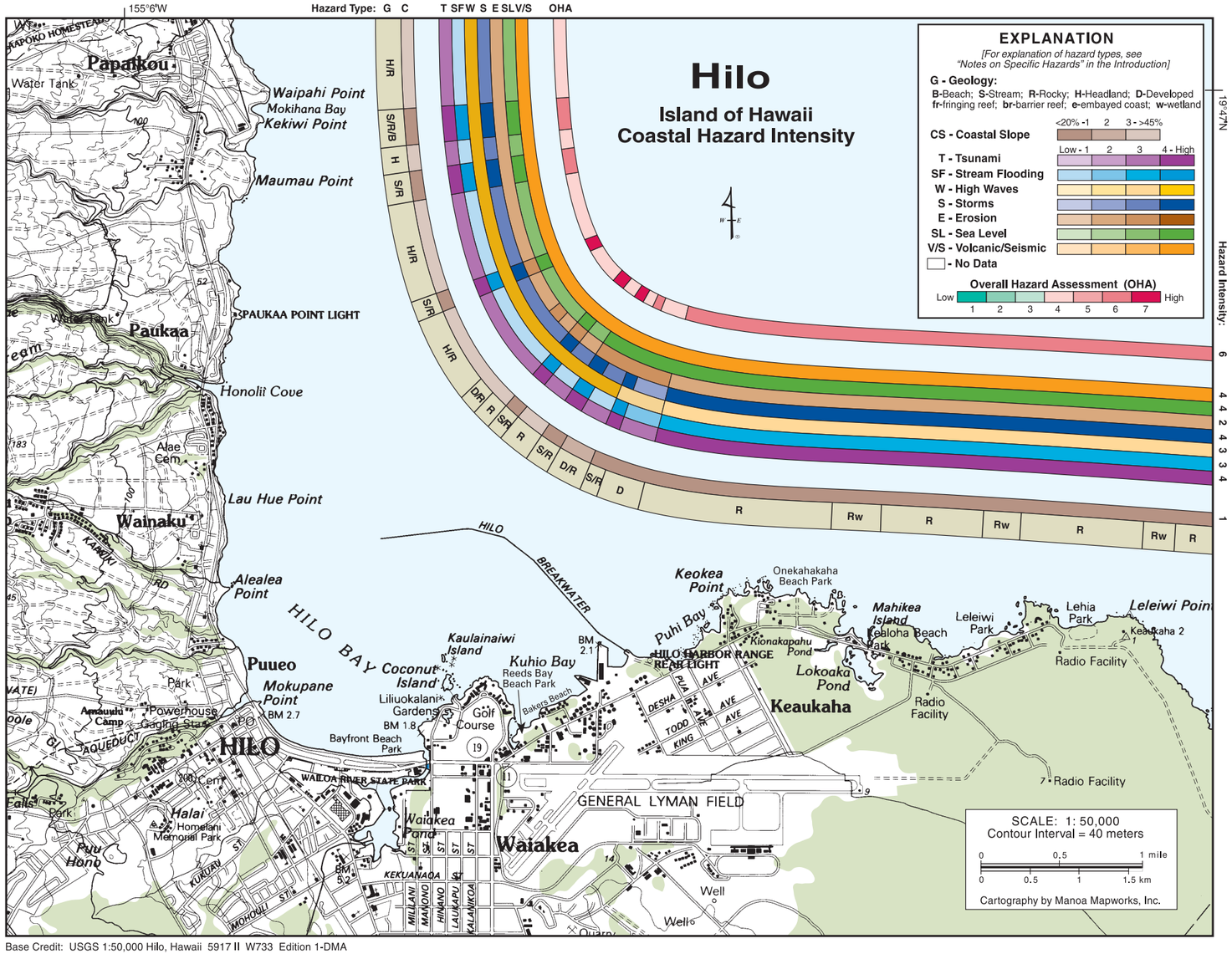
Hilo

The embayed and heavily developed Hilo coast becomes progressively more gently sloping and low lying toward the south. The city of Hilo is situated in a saddle between the Mauna Kea and Mauna Loa Volcanoes. Numerous streams that drain the Mauna Kea side of the Hilo hinterland have been infilled by Mauna Loa lavas that flowed northward as recently as 1984. Fortunately for the town of Hilo, these lavas only reached the upper city limits. Perhaps more of a concern to Hilo residents is the potential future impact of tsunami. Two devastating tsunamis in roughly the last 50 yr, generated by the 1946 Alaskan and 1960 Chilean earthquakes, inundated the town of Hilo with runups of 26 and 35 ft, respectively, destroying much of the central business region.

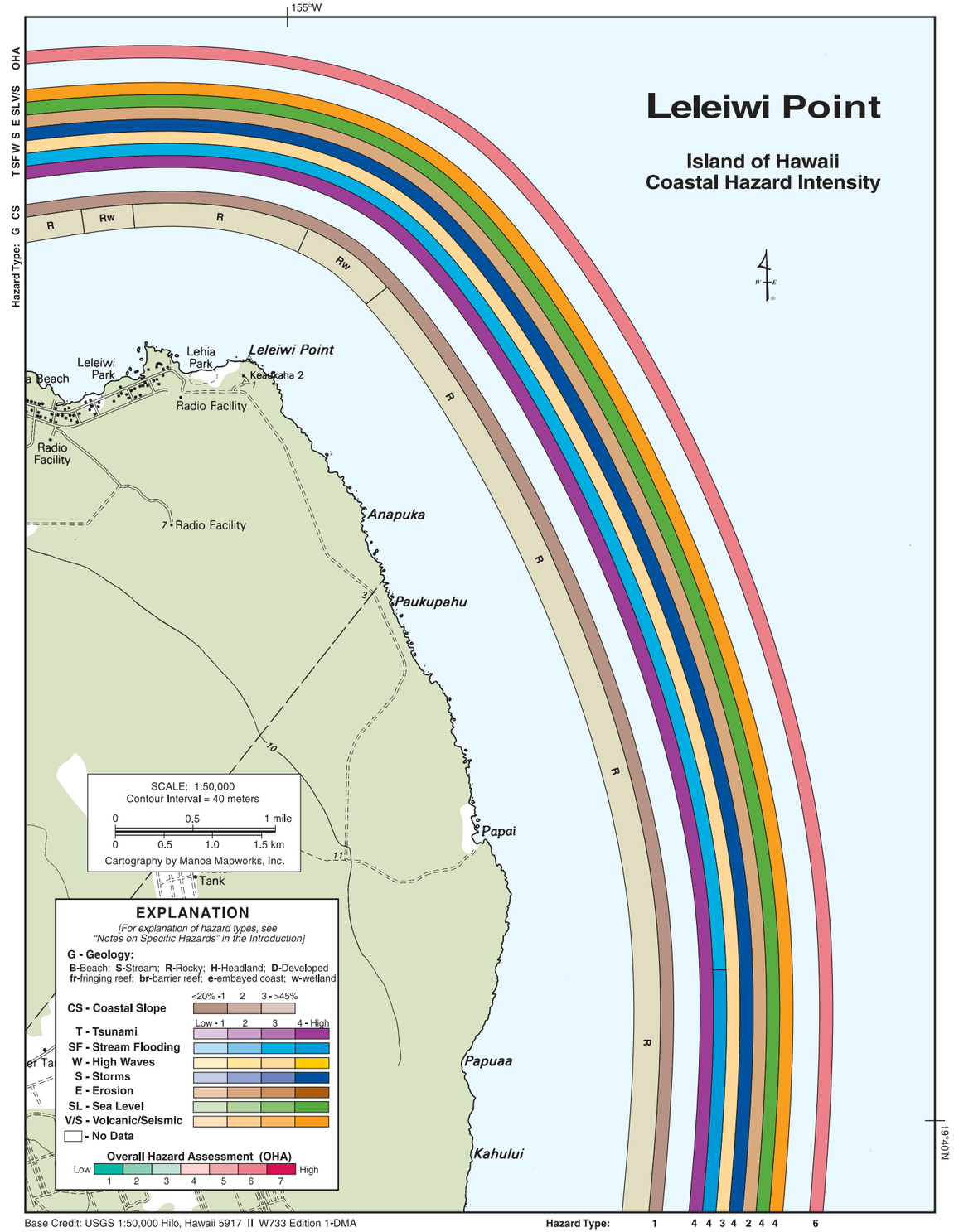
Narrow black sand beaches extend along the Hilo bayfront and at Reeds Bay Beach Park and Bakers Beach where coral sand and rubble beaches have been lost due to erosion since they were constructed in the late 1920's. To help protect the bayfront shoreline from a long history of tsunami and wave action, the L-shaped Hilo Breakwater was built in the early 1900's. Numerous small pocket beaches are found east of the breakwater, most separated from the sea by natural lava flows and/or retaining walls like the wall at Richardson Ocean Center at Leleiwi Beach Park. Erosion and sea-level rise are important components of shoreline change in the Hilo area. Nearly 50 years of tide gauge data show that the Big Island near Hilo is subsiding in addition to experiencing global sea-level rise. This makes relative sea-level rise in Hilo (1.63 inches/decade) faster than on Oahu (0.64 inches/decade) and Maui (0.96 inches/decade). Erosion along the coast is largely controlled by this rapid rate of sea-level rise.

The Overall Hazard Assessment (OHA) for the Hilo region alternates between moderate (4) along the rocky headland regions in the north to high (6) and very high (7) at stream mouths within and east of Hilo Bay. The tsunami, high wave, storm, and sea-level-rise hazards are moderately high at the rocky headlands, while stream flooding is low and erosion is moderately low. The rankings for tsunami, stream flooding, storm, and sea-level rise are high along the lower-lying coastal segments, especially stream mouths. Inside Hilo Bay, where erosion is moderately high, the OHA is very high (7). High waves are partly mitigated by the breakwater, so the coastal region of Kuhio Bay has a high wave ranking of moderately low and an OHA of moderate (4). East of the Hilo Breakwater the OHA is high (6), reflecting the uniform gently-sloping coastal zone and moderately high stream flooding hazards there. Hilo lies within lava flow hazard zone 3 (Table 10, p. 24). The volcanic/seismic hazard is high in Hilo as it is along the entire Big Island coast which experiences active seismicity associated with Kilauea Volcano.

The extensively developed Hilo coast is low lying and prone to flooding by heavy rainfall and tsunami inundation. The Hilo breakwater helps to mitigate flooding from storm-wave surge associated with high annual north swell, episodic tropical storms, and tsunami inundation.



Base Credit: USGS 1:50,000 Hilo, Hawaii 5917 II W733 Edition 1-DMA



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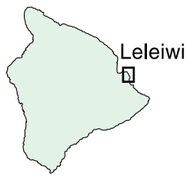


Leleiwi Point

The Leleiwi Point coastline is largely fronted by low lava cliffs formed by the Kau Basalt, which ranges between 350 and 500 yr old. These historical lava flows spread toward the sea forming jagged headland points and small rocky islets which are especially numerous between Anapuka and Papai. The elevation of the relatively undeveloped volcanic coastal terrace ranges between 10-15 ft above sea level. Leleiwi and Lehia Parks harbor small pocket beaches within the rocky coves. A narrow black and olivine-rich green sand beach lines the inner portion of Papai Bay. Freshwater springs are common along this stretch of coast, often creating a cold freshwater lens near the surface and brackish conditions in the rocky pools behind the points. The Leleiwi Point shoreline faces directly into the prevailing northeast trade winds and receives significant wave energy originating from north, east, and southeast swell. Corals are sparse in this region.

The high (6) Overall Hazard Assessment (OHA) for Leleiwi Point coast is largely a function of the low coastal slope along the entire coastline, which is susceptible to marine overwash and stream flooding. However, because it is partly removed from the watersheds that drain Mauna Loa and Mauna Kea Volcanoes around Hilo, the stream-flooding threat is ranked only moderately high. Tsunami is ranked high while the threat from high waves is only moderately high because of its northeast aspect. High winds from approaching tropical cyclones and Kona storms impact this northeast-facing shoreline and so the storm hazard is ranked high. Erosion is partly mitigated by the rocky cliffs that line the coast, so the erosion threat is ranked moderately low. Sea level is rising relative to the island land mass faster in this region than any other in Hawaii. The Leleiwi Point coast lies in lava flow hazard zone 3 (Table 10, p. 24). This portion of Hawaii also experiences very active seismicity associated with volcanism at Kilauea Volcano. As a result, these two hazards are ranked high.

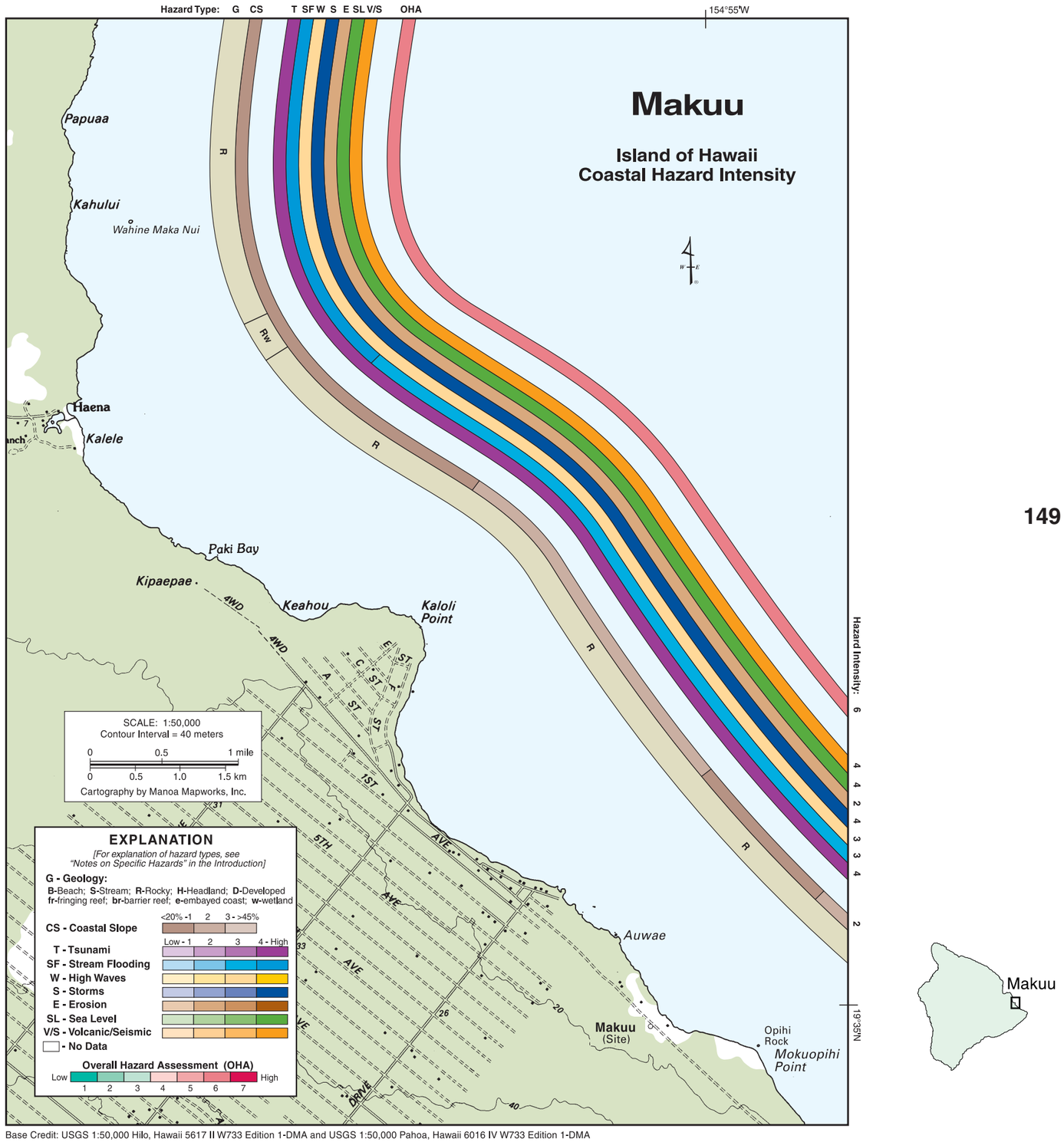
The area around Leleiwi Point consists of low lying rocky points and gravel-filled embayed beaches.

Makuu

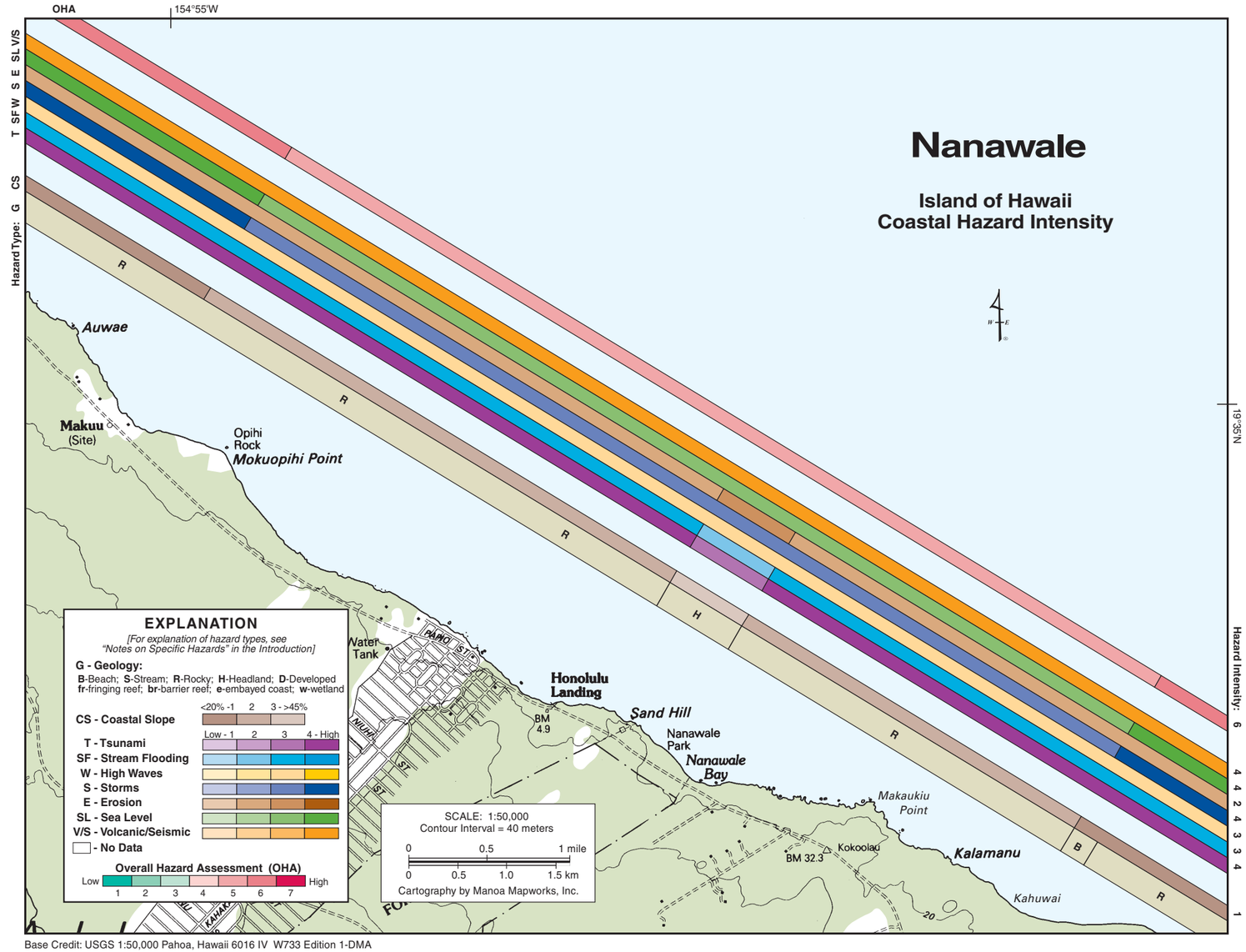
Between Papuaa and Kaloli Point, the Makuu coast is only slightly developed, however south to Auwae, the coast is well developed with the Hawaiian Paradise Park subdivision extending to the shoreline. The Makuu coastal terrace is comprised of Ai-Laau lava flows which are between 350 and 500 yr old. The entire coastline is within 20 ft of sea level and appears to be getting closer due to steady long-term and rapid periodic subsidence. In April of 1868 the region sank and was inundated by a locally generated tsunami after a 4.1 earthquake rocked the southeast portion of the island. The small spring-fed wetland pond and inlet at Haena are the products of shoreline change due to the April 1868 co-seismic subsidence. A thin veneer of carbonate sand covers the bottom of Haena Bay. Low sea cliffs border the shore between Kaloli and Mokuopihi Points. The only beaches in this region are low lying, narrow, and limited to the base of the cliffs along the Hawaiian Paradise Park subdivision and Makuu. South of Paki Bay the coastal terrace becomes slightly more arid and fewer streams cross it to the sea.

The Overall Hazard Assessment (OHA) for the entire Makuu coast is high (6), reflecting the high and moderately high hazards that affect this low-lying region. The tsunami threat is ranked high, while stream flooding is high in the northern portion but only moderately high south of Paki Bay, where fewer streams reach the sea. High waves consist generally of refracted north swell, trade-wind waves, and waves associated with approaching tropical cyclones. As a result, the high wave hazard is ranked moderately high. The storm hazard is high where the coast is exposed to both the tropical cyclone and Kona storm windows. This seismically and volcanically active coast experiences rapid long-term subsidence which enhances the rate of relative sea-level rise. For this reason the sea-level hazard is high. Makuu is located in lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic hazard is high along the Makuu coast due to the high lava flow hazard and its proximity to significant seismic activity generated by volcanic eruptions at Kilauea Volcano.

Most of the east-facing Makuu coast consists of rugged and rocky cliffs generally less than 20 ft high.



Base Credit: USGS 1:50,000 Hilo, Hawaii 5617 II W733 Edition 1-DMA and USGS 1:50,000 Pahoa, Hawaii 6016 IV W733 Edition 1-DMA



Base Credit: USGS 1:50,000 Pahoa, Hawaii 6016 IV W733 Edition 1-DMA

Nanawale

Southeast of Auwae and Mokuopihi Point, the Nanawale coast ranges from 1000 to 1500 yr old, except the area between Honolulu Landing and Nanawale Park, which is the seaward edge of an 1840 flow that emanated from the east rift of Kilauea Volcano. Most of the coast is fronted by low rocky sea cliffs, above which is built the Hawaiian Beaches subdivision in the middle of this portion of coastline. A few small boulder beaches occur at Honolulu Landing, Nanawale Park, and along the southern stretch of coast to Kahuwai. The black sand beach at Kahuwai formed shortly after the 1960 Kapoho eruption which sent lava flowing into the sea just southeast of the Nanawale region. The Nanawale shoreline undergoes periodic morphologic changes due to tectonic and seismic activity associated with Kilauea Volcano. In April of 1924, a series of earthquakes caused the Honolulu Landing shoreline to sink, leaving the black sand beach buried in rounded basalt boulders and the boat landing less used by larger ships. High waves are common along the Nanawale coast often making the rugged coastal cliffs dangerous for fishermen.

The Overall Hazard Assessment (OHA) for the Nanawale coast is reduced from high (6) north of Makuu to moderate to high (5) south of Makuu to Kalamanu where the coast steepens and the sea cliffs help to mitigate against marine overwash and the impacts associated with sea-level rise. To the south of Makuu the tsunami hazard is ranked high while stream flooding is moderately high. An anomaly exists at the Sand Hill headland. Here the coast is even steeper, so flooding hazards are less threatening, but because the substrate is more unconsolidated it is more susceptible to erosion. As a result, tsunami and stream flooding at Sand Hill are moderately high and moderately low, respectively. The high wave threat is moderately high throughout Nanawale. The storm and sea-level hazards are ranked moderately high between Makuu and Kalamanu. Erosion is moderately low except at Sand Hill where it is increased to moderately high. The Nanwele coast is in lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic hazard is high throughout the entire region due to its proximity to great seismic activity associated with Kilauea volcanism.

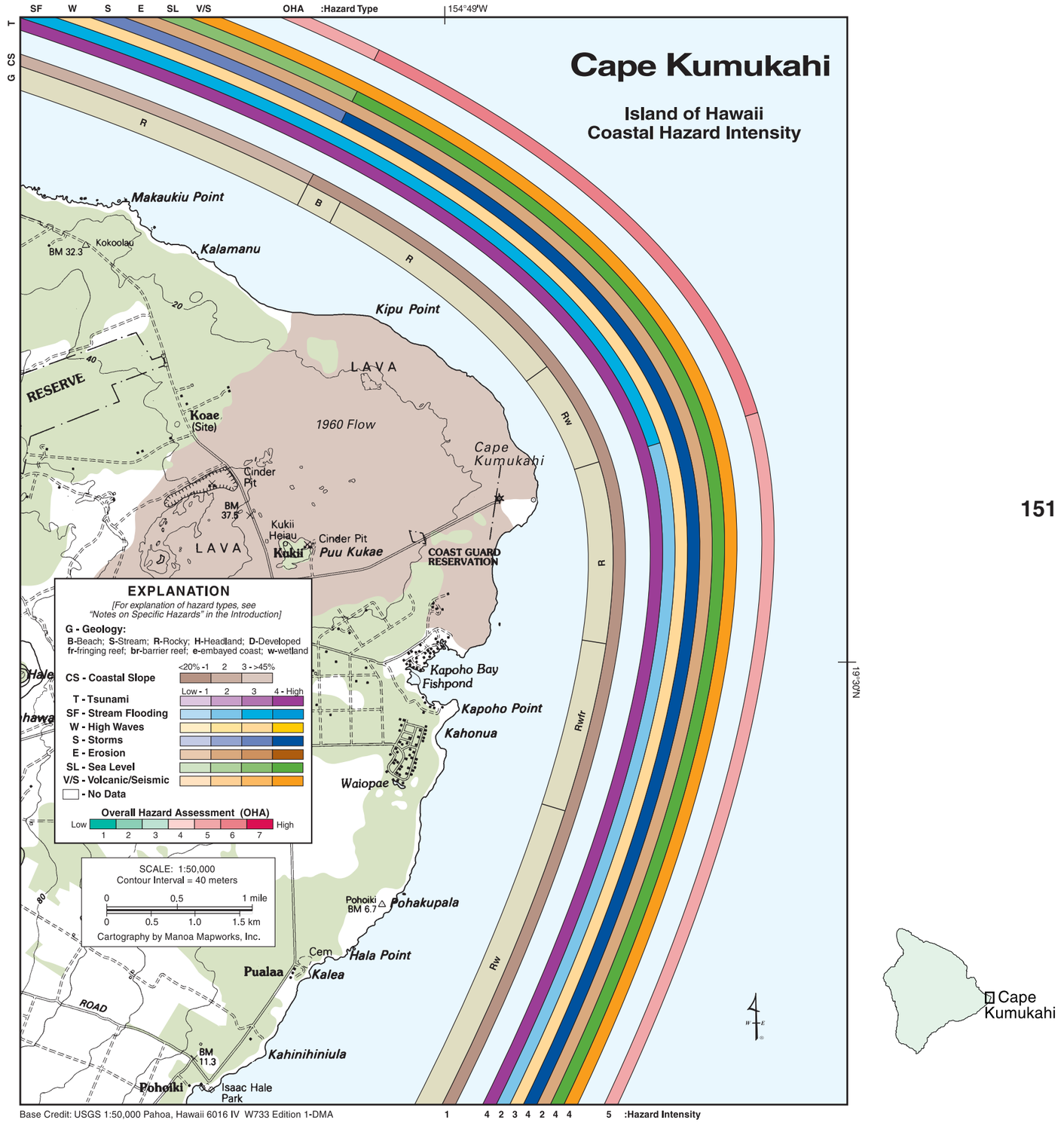
The geologically young volcanic coast of Nanawele is rocky with small cliffs and few beaches or reefs.

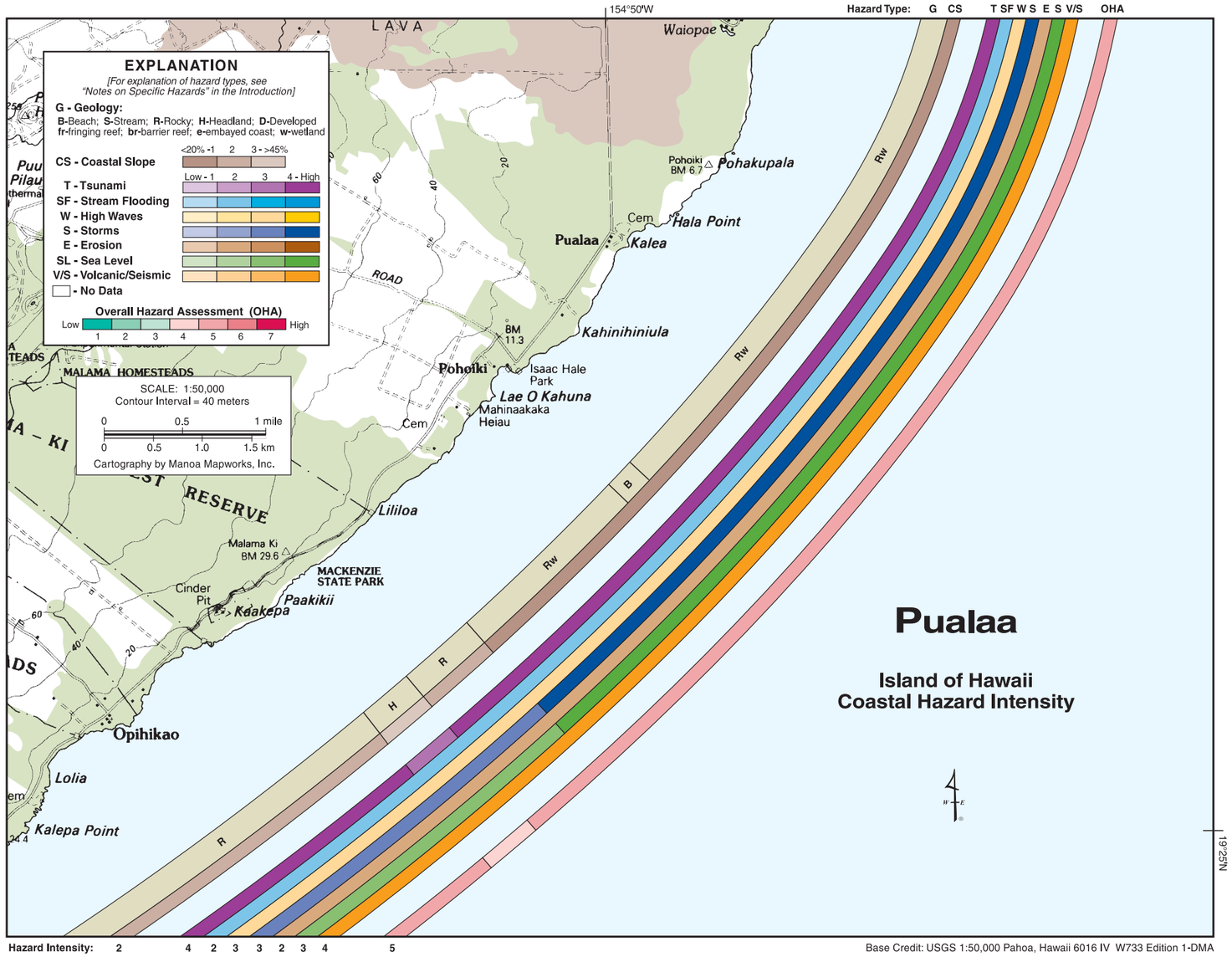
Cape Kumukahi

The 1960 Kapoho eruption along Kilauea Volcano's east rift zone produced lava flows that extended parts of Cape Kumukahi, the eastern-most point in Hawaii, farther seaward and eastward. The entire village of Kapoho, and most of Koae, was destroyed. Rock walls emplaced by the inhabitants of the area however, served to protect the lighthouse and houses to the south. The flow produced a black sand beach that temporarily existed along the 3 miles of Kumukahi, but was soon lost to the relentless attack of trade-wind and storm-generated waves. Cape Kumukahi is located directly on Kilauea's east rift zone and is therefore classified into lava flow hazard zone 1 (Table 10, p. 24). Development remaining along this coast is focused at Kapoho Bay where tidepools abound and a fish pond provides a wetland habitat for various species of birds. South of Kapoho Point, a fringing reef extends just past Kahonua along a generally rocky coast that borders the Pualaa coastal terrace to Kalea. Rainfall and stream flow decrease markedly south of Cape Kumukahi. This coast receives significant wave energy from trade-wind and east and south swell, as well as refracting north swell.

The Overall Hazard Assessment (OHA) for Cape Kumukahi is largely dictated by the coastal slope and presence or absence of streams. The slope decreases south of Kalamanu and the hazards associated with flooding and sea level are therefore generally higher south of this point. However, south of the lighthouse at Cape Kumukahi streams are absent thus reducing the stream flooding hazard. The tsunami hazard is high, while the high wave threat is ranked moderately high along this entire low lying coast. Stream flooding is moderately high north of Cape Kumukahi and only moderately low to the south. The storm and sea-level hazards are increased from moderately high to high south of Kalamanu where the coastal slope becomes more low lying and gentle. Erosion is ranked uniformly moderately low throughout the entire sea-cliffed coast. The volcanic/seismic hazard is high along Cape Kumukahi due to historical volcanism and seismicity associated with eruptions of Kilauea Volcano. As a result, the OHA is moderate to high (5) north of Kalamanu, high (6) between Kalamanu and Cape Kumukahi, and moderate to high (5) in the southern portion between the cape and Pualaa.

The Cape Kumukahi coast is generally low lying and formed by recent lava flows that have emanated from Kilauea Volcano's east rift zone.





Pualaa

Between Pohakupala and Opihikao, the Pualaa Coast is lined by low rocky sea cliffs that face southeast. The coast steepens south of Lililoa and at a small headland at Paakikii. Most of the lavas that form the coastal terrace and its cliffs range in age between 250 and 1000 yr, however the youngest outcropping between Lililoa and Mackenzie State Park is associated with a 1790 flow. This region, like most of the Puna district to the north, is geothermally very active. Hot springs and fumaroles or vents of escaping gas can be seen emanating through the Pualaa coastal terrace. The surfacing of these waters creates wetland environments along the entire coast. The only beach in this portion of coast is found at Isaac Hale Park inside Pohoiki Bay. Here warm water seeps into Pohoiki Bay through the bay floor. The Pualaa coast receives between 75 and 100 in of rain annually and has few streams. High waves persistently attack the coastal cliffs making access to the water relatively dangerous. No significant reef development exists on this geologically young coastline.

The Overall Hazard Assessment (OHA) for Pualaa is moderate to high (5) except at Paakikii where it is moderate (4). This variation is due to the change in coastal slope at Paakikii. Here the tsunami hazard is reduced to moderately high from a ranking of high along the rest of the coast. Stream flooding is moderately low throughout this relatively arid region. The high wave hazard is moderately high along the entire coast while the storm and sea-level hazards are high north of Lililoa and reduced to moderately high to the south where the coast is steeper. Erosion along the rocky Pualaa coast is ranked uniformly moderately low. Pualaa lies in lava flow hazard zone 2 (Table 10, p. 24). The seismicity and volcanic hazard is high due to this region's proximity to the active Kilauea Volcano.

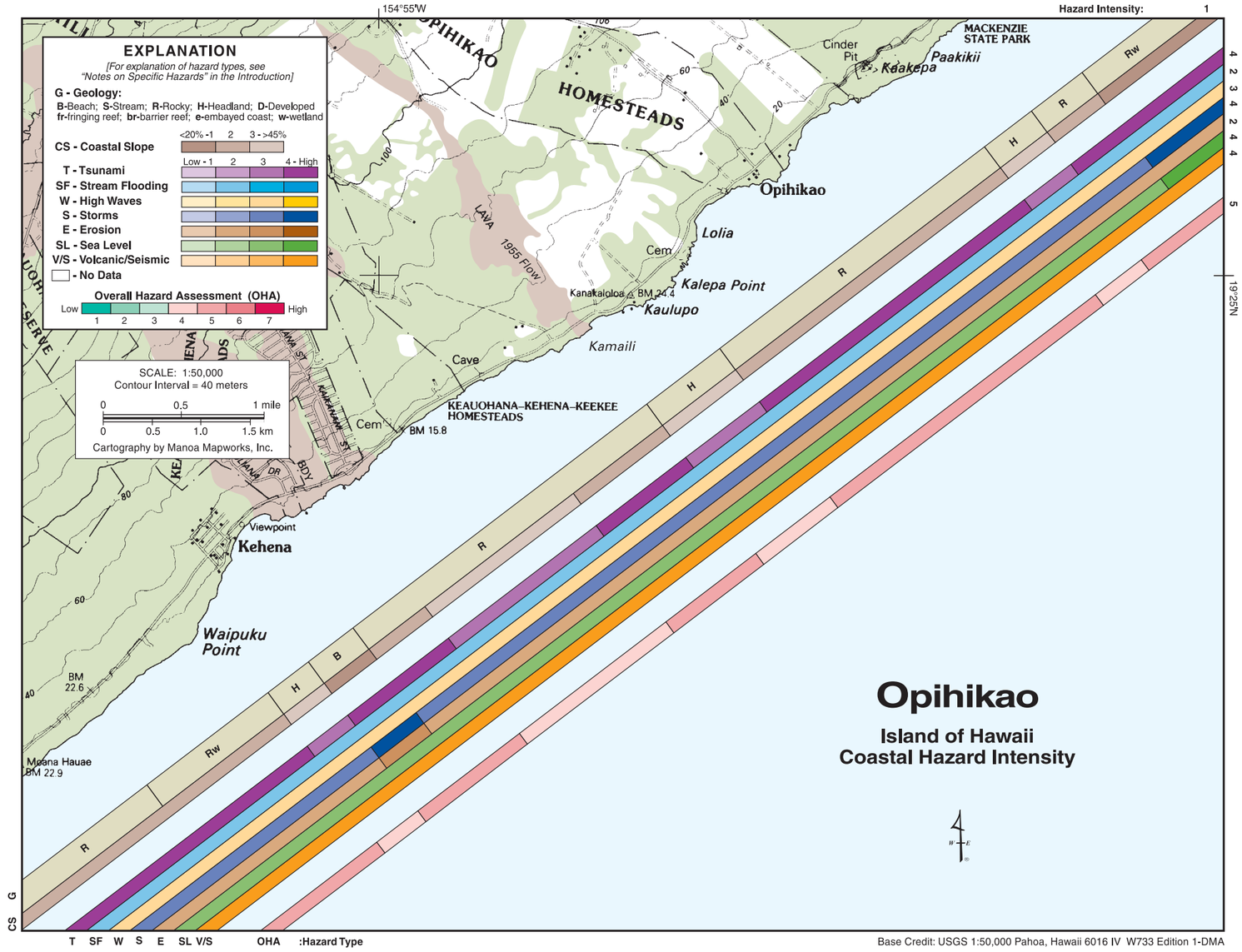
The Pualaa coast is rocky and low lying with occasional small embayments providing protection from side shore winds and generally rough seas.

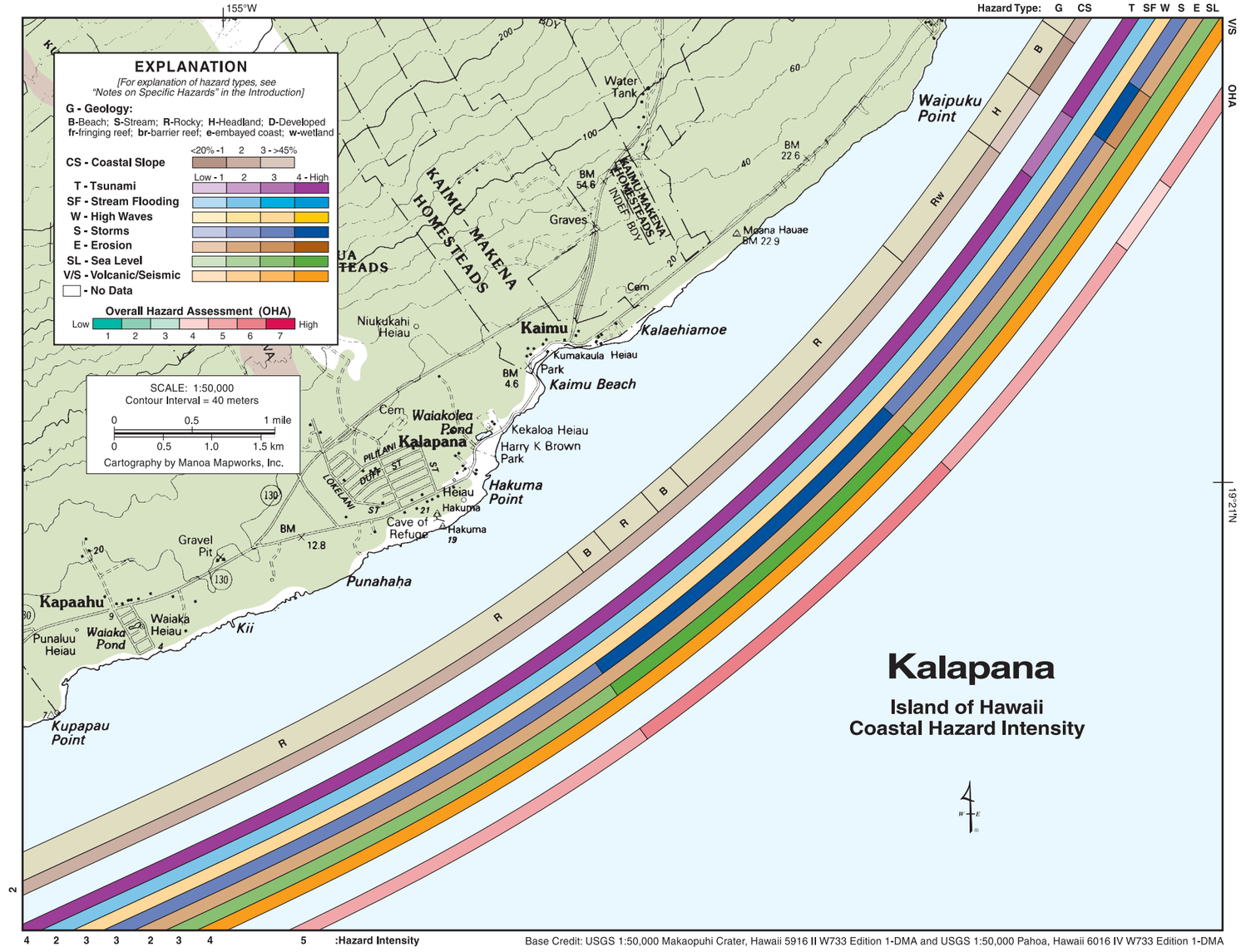
Opihikao

The Opihikao shoreline between Paakikii and Waipuku Point has been built over the past several thousand years by numerous lava flows. However, as recently as 1955, a significant volume of lava erupted from Kilauea Volcano's east rift and created new coastline at Kamaili and the Keauohana-Kehena-Keekee Homesteads. The 1955 flow is responsible for the formation of the black sand beach at Kehena and a small rocky point that appears to help mitigate against erosion of the beach. Unlike other beaches in this region, the Kehena beach has survived the attack of waves and earthquake-induced subsidence. In 1975, the beach sank nearly three feet when a 7.2 magnitude earthquake rocked the entire southern corner of the island. Relatively intense wave energy maintains a steep beachface at Kehena, where pebbles and cobbles are common. Just offshore of most of the Opihikao coast the seafloor drops off rapidly. Very few corals have managed to colonize this region of coast.

The Overall Hazard Assessment (OHA) for Opihikao alternates between moderate to high (5) and moderate (4). Stream flooding and storms are ranked moderately low and moderately high, respectively, while the volcanic/seismic threat is high throughout the entire region because of the proximity to Kilauea Volcano. Along the headlands at Paakikii, Kaulupo, Waipuku, and the rocky coast of the Keauohanaa-Kehena-Keekee Homesteads, the OHA is moderate (4) where tsunami, high waves, and sea-level rise are moderately high and stream flooding and erosion are moderately low. Between these headlands where the coast is lower, the tsunami hazard is ranked high and so the OHA is increased to moderate to high (5). At the beach inside the Kehena embayment the storm and erosion hazards are elevated to high and moderately high, respectively. The Opihikao coast lies within lava flow hazard zone 2 (Table 10, p. 24).

Recent lava flows have covered pre-existing vegetation and infrastructure along the low-lying, rocky Opihikao coast.





Kalapana

The Kalapana coast is famous for its beautiful black sand beaches. At times, these beaches are instantaneously created and at others, rapidly destroyed by the lava flows that form the coastline. In 1992, lava flows emanating from Kilauea Volcano's east rift zone buried the once popular Kalapana black sand beach and extended the coastal terrace over 1500 ft seaward in the form of a table of pahoehoe. In addition to volcanic eruptions and lava flows, earthquakes and rapid tectonic subsidence have shaped the coast here, creating and destroying beaches, bays, and points of entry for boaters and fishermen. Most of the coastline between Waipuku and Kupapau Points is bordered by cliffs that mark the seaward limit of lava flows protruding into the sea. Small black sand pocket beaches, including those at Harry K. Brown Park and Kaimu, may only exist temporarily as they appear to be losing ground to the sea since their formation in 1992. This coast is very young and, as a result, there is little coral reef development.

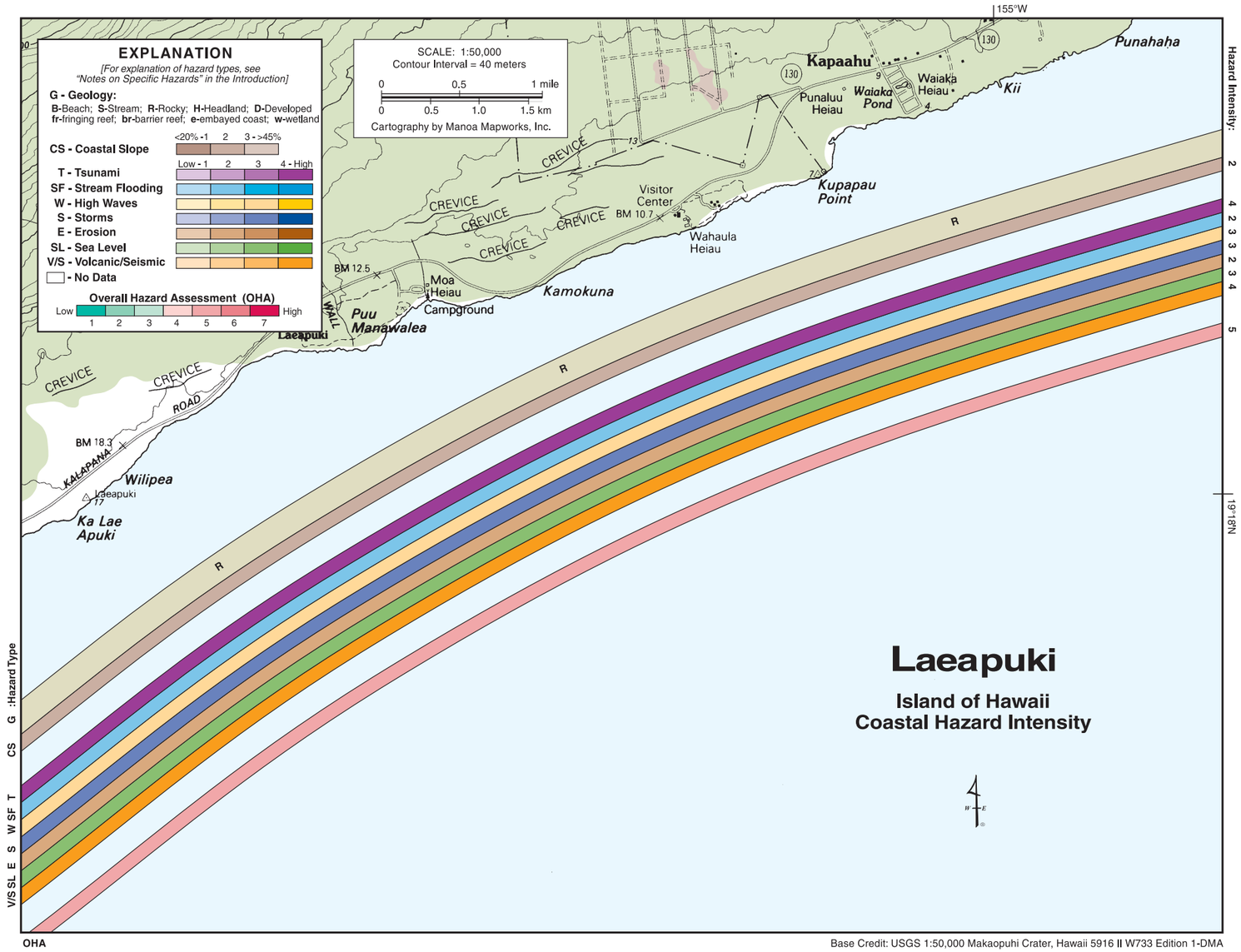
The Overall Hazard Assessment (OHA) is moderate to high (5) south of Hakuma Point and north of Moana Hauae, except for the headland of Waipuku Point where it is moderate (4), and seaward of the low-lying beach area of Kaimu Beach where it is high (6). Tsunami is high along this low-lying stretch of coast except at the headland south of Waipuku Point, where it is moderately high. Stream flooding is moderately low in this relatively arid region where few streams flow to the sea. The high wave threat is ranked moderately high. Storms are ranked high south of Kalaehiamoe, and moderately high to the north except along the beach just north of Waipuku Point where it is high. Erosion is moderately low except at this same beach where it is moderately high. Sea-level rise is moderately high along the headland coast in the north, and high along the lower-lying cliffs south of Moana Hauae. The volcanic/seismic hazard is high along the entire Kalapana coastline because of its proximity to active volcanic and seismic activity associated with Kilauea Volcano eruptions. Kalapana lies within lava flow hazard zone 2 (Table 10, p. 24).

Lava flows reached the coast at Kalapana in 1992, extending the shoreline seaward nearly 2500 ft, burying the famous Black Sand Beach under a fresh platform of black lava rock. Small transient black sand beaches have formed downdrift of the new lava coast, but have been highly susceptible to erosion due to rapid sea-level rise.

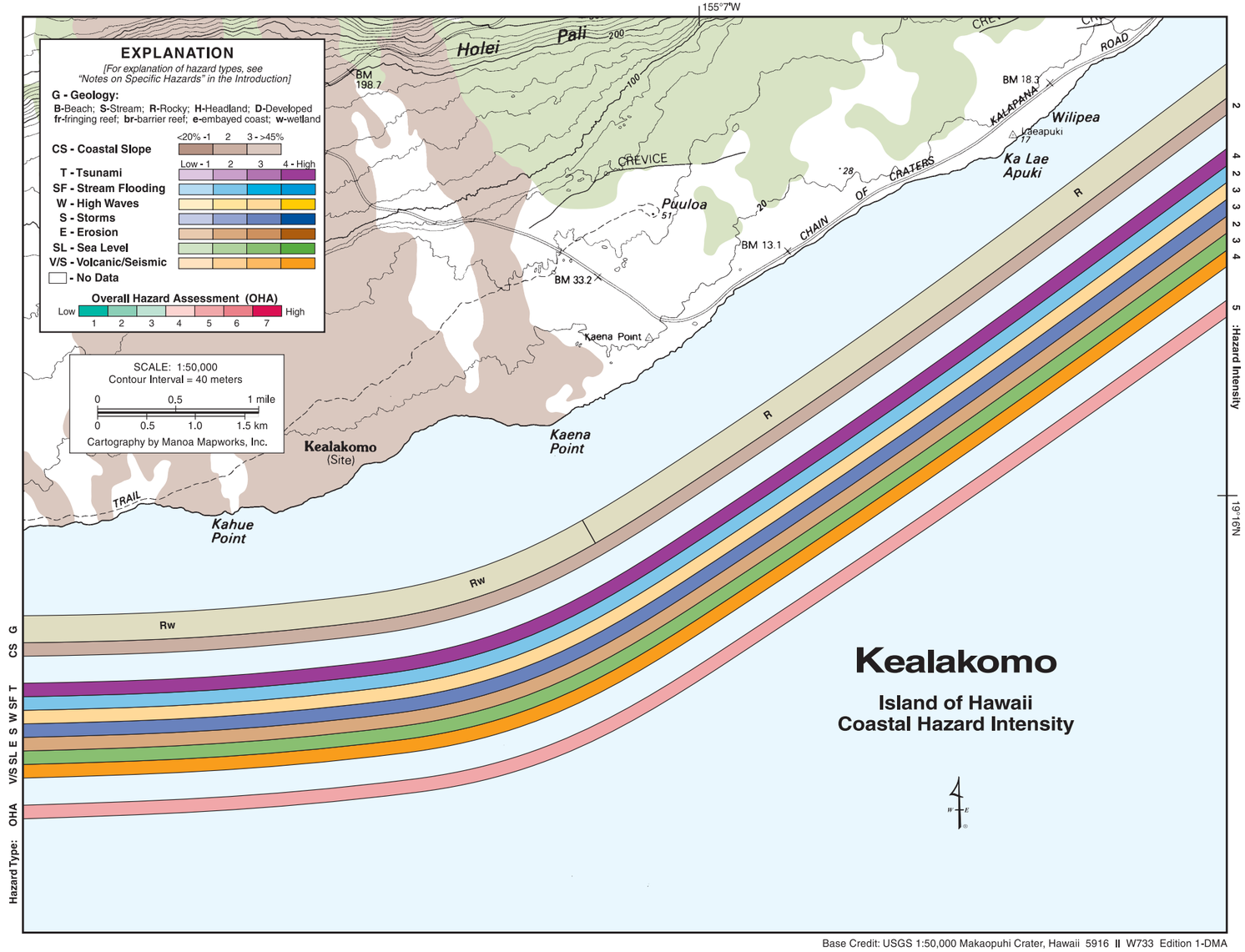
Laeapuki

The low-lying rocky Laeapuki coastline is undergoing significant change as this atlas is being printed. Since 1992, lava flows from numerous eruptions at Puu Oo along Kilauea Volcano's southeast rift have built the shoreline seaward and cut off the coastal road from the east. Billowing clouds of steam mark the entry of molten rock into the sea as it cascades over small 3-10 ft high sea cliffs. Often the flowing lava is absent on the surface as it travels through subsurface lava tubes and porous conduits. The ceilings of these lava tubes are essentially the top surface of the flow, and these can collapse if they are unable to support the burden placed upon them. This mechanism also works on a large spatial scale as the underlying porous framework of thousands of years of lava accumulation periodically gives way to the mass above in the form of slow creep and rapid subsidence. It is now believed that the entire south flank of Kilauea slides seaward at a slow uniform rate of approximately 0.5-1 in/yr and in rapid and recurrent down-faulting steps. Few corals keep up with the changing coastal environment here.

The uniform moderate to high (5) Overall Hazard Assessment (OHA) for Laeapuki reflects a similar ranking of the individual hazards along this constant sloped coastline. The tsunami hazard is high. Stream flooding and erosion are both moderately low in this arid and rocky cliffed region. The high wave and storm threats are moderately high here where the coast receives moderately high south swell and approaching storm winds and waves. Despite the high rate of island subsidence, sea-level rise is ranked only moderately high due to the mitigating effects of the rocky cliffs. The Laeapuki coast lies in lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic hazard is high due to the active volcanism and seismicity associated with Kilauea Volcano eruptions that constantly affect the Laeapuki coast.



The Laeapuki coast is actively being transformed at the time of publication of this atlas. As lavas emanating from Puu Oo and its subsurface network of lava tubes reach the coast, the shoreline at Laeapuki temporarily extends seaward and occasionally collapses under its newly found weight, making it very unstable.



Base Credit: USGS 1:50,000 Makaopuhi Crater, Hawaii 5916 II W733 Edition 1-DMA

The undeveloped and geologically young Kealakomo coast is fronted by steep sea-cliffs ranging 5 to 15 ft high. It is low lying and gradually slopes landward to the base of the Halina and Holei palis (cliffs).

Kealakomo

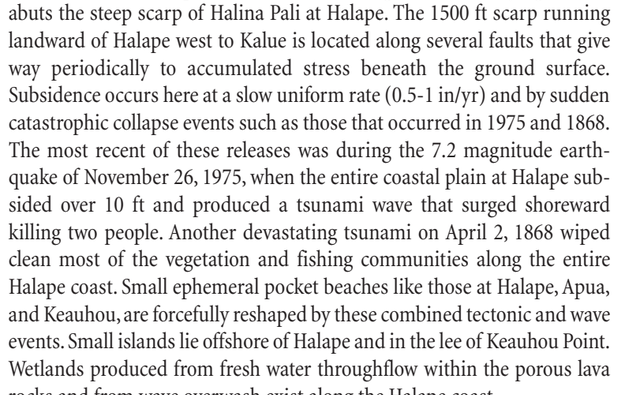
The Kealakomo coast is currently one of the most volcanically active coasts in Hawaii. Lava flows emanating from Puu Oo, seven miles landward on Kilauea Volcano's southeast rift, have continuously reshaped the eastern portion of this area and cut off the Chain of Craters Road from the east since 1992. Here molten lava cascading down Kilauea's seaward slopes have created a 1000-1500 ft wide coastal terrace that ranges between 3 and 12 ft above sea level. Behind it a steep 60-100 ft high scarp, or pali, breaks the coastal slope. To the west, the coastal terrace widens where lavas from the Mauna Ulu eruptions of 1969-1971 extended the coast seaward. The entire stretch of coast is rocky and bordered by steep sea cliffs. Despite the aridity, the high porosity of the rocks formed by these lava flows enables fresh water to seep toward the coast sometimes making small wetlands like those west of Kaena Point. High porosity of the underlying rocks also means less structural support and sink holes and collapse features are common. Offshore the seafloor is rocky and void of any reef development.

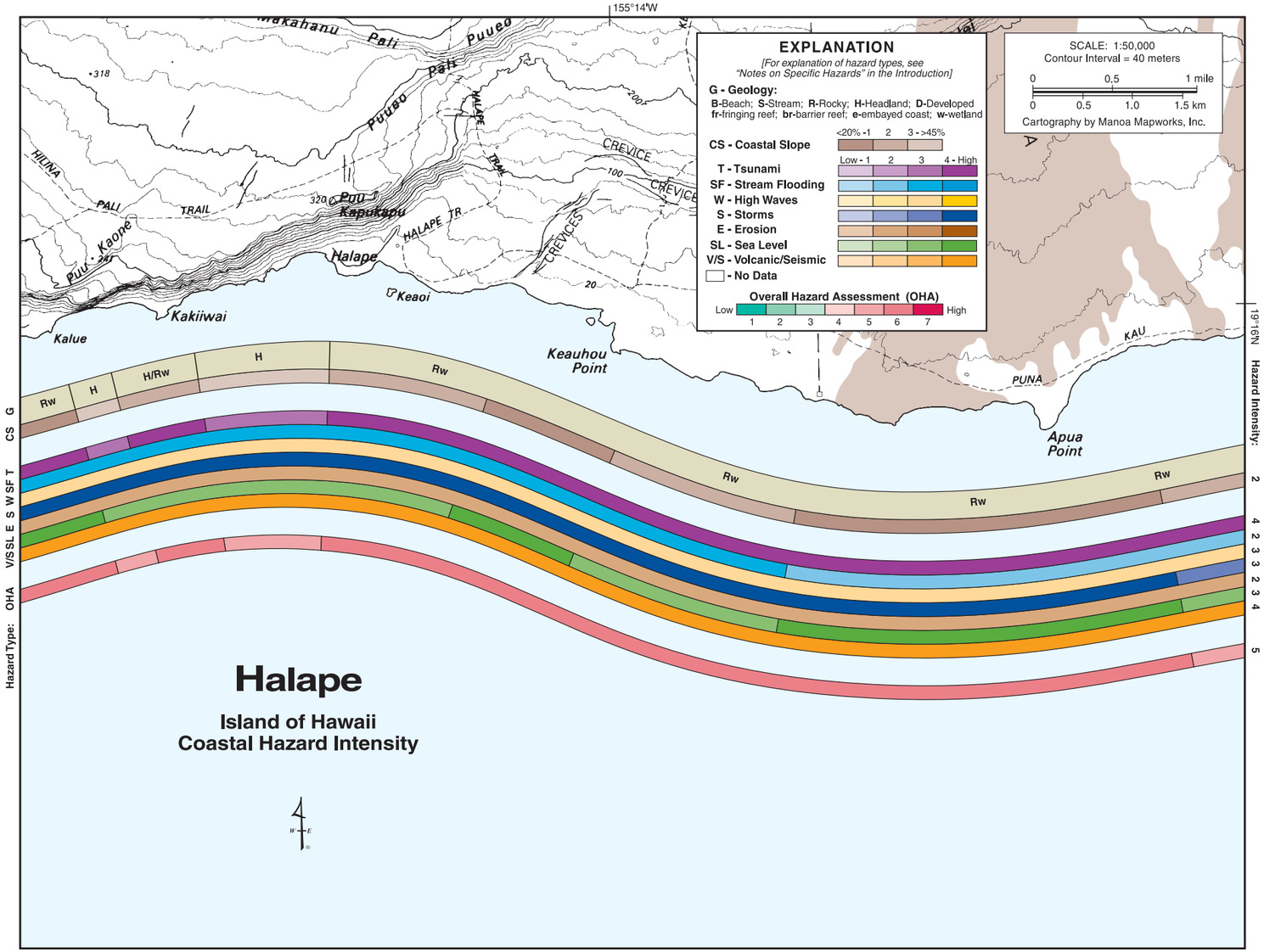
The Overall Hazard Assessment (OHA) along the entire Kealakomo coast is moderate to high (5) due to the uniform ranking for the individual hazards. This is largely a result of the uniform rocky shoreline and low slope found along the entire coast. Tsunami is high, while stream flooding is moderately low in this arid region. High waves and storms are ranked moderately high, because this coast receives significant swell from the south and winds and waves from approaching storms. Erosion is moderately low along this geologically young, cliffed coast. Sea-level rise is moderately high and the volcanic/seismic hazard is high. The Kealakomo coast lies within lava flow hazard zone 2 (Table 10, p. 24).

Halape

The wide volcanic coastal terrace most recently built seaward by the Mauna Ulu eruptions of 1969-1974 is generally low lying until it abuts the steep scarp of Halina Pali at Halape. The 1500 ft scarp running landward of Halape west to Kalue is located along several faults that give way periodically to accumulated stress beneath the ground surface. Subsidence occurs here at a slow uniform rate (0.5-1 in/yr) and by sudden catastrophic collapse events such as those that occurred in 1975 and 1868. The most recent of these releases was during the 7.2 magnitude earthquake of November 26, 1975, when the entire coastal plain at Halape subsided over 10 ft and produced a tsunami wave that surged shoreward killing two people. Another devastating tsunami on April 2, 1868 wiped clean most of the vegetation and fishing communities along the entire Halape coast. Small ephemeral pocket beaches like those at Halape, Apua, and Keauhou, are forcefully reshaped by these combined tectonic and wave events. Small islands lie offshore of Halape and in the lee of Keauhou Point. Wetlands produced from fresh water throughflow within the porous lava rocks and from wave overwash exist along the Halape coast.

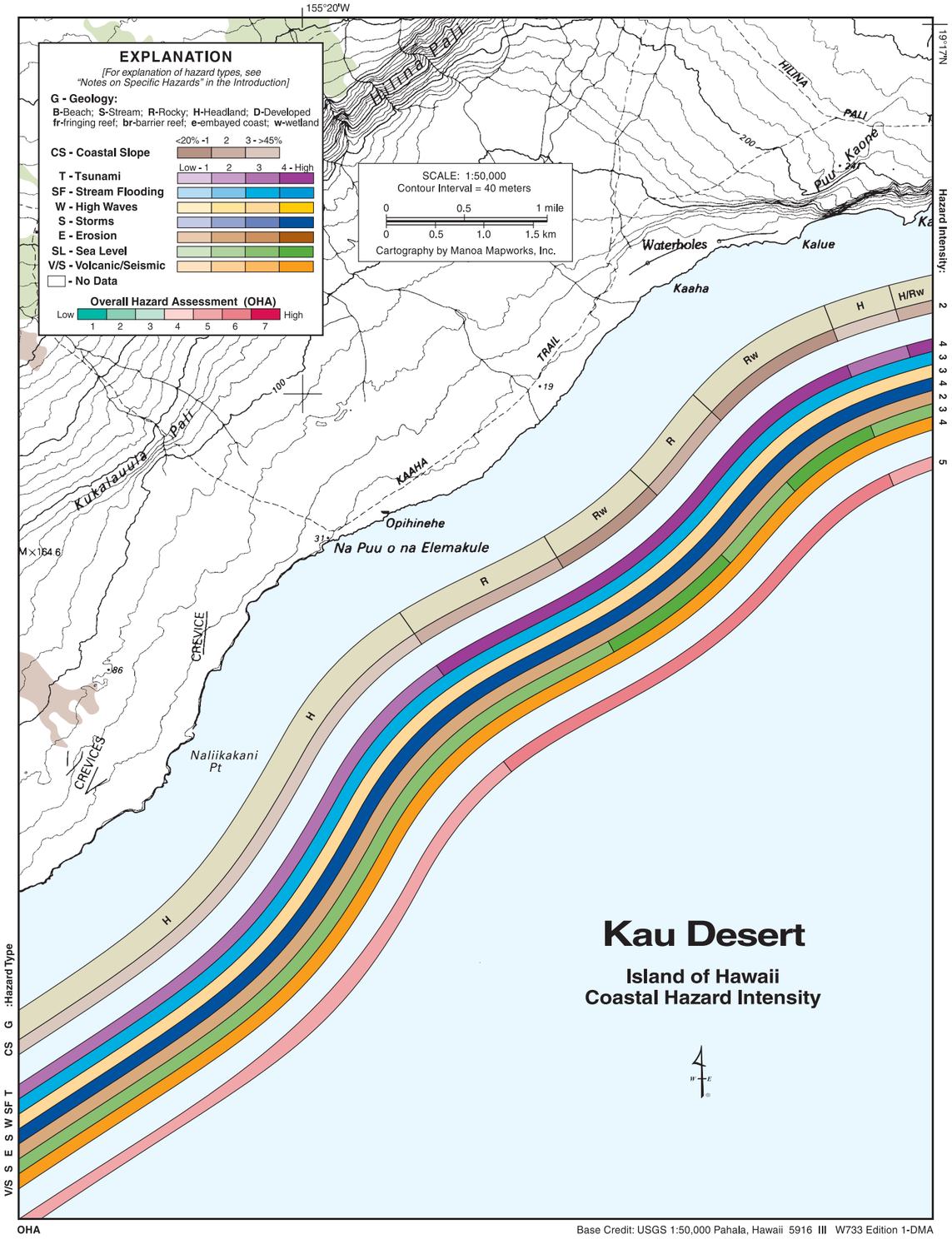
Variations in coastal slope dictate the different hazard rankings along the Halape coast. The Overall Hazard Assessment (OHA) is moderate to high (5) east of Apua Point, and alternates between high (6) and moderate to high (5) to the west. The tsunami hazard is high along the entire coast except at the headlands near Kakiiwai and Kalue, where it is reduced to moderately high. The stream flooding threat increases from moderately low to moderately high west of Apua Point, where stream channels have yet to be covered by recent volcanic activity. High waves and storms are moderately high and high, respectively, west of Apua Point. Erosion is moderately low along this rocky cliffed coast, while sea-level rise is ranked high along the low-lying sections near Apua, Keauhou, and Kalue Points, and moderately low along the headlands in between. The Halape coast lies in lava flow hazard zone 5 (Table 10, p. 24). The volcanic/seismic hazard is uniformly high throughout the Halape coast due to significant seismic activity associated with Kilauea Volcano eruptions.





Base Credit: USGS 1:50,000 Makaopuhi Crater, Hawaii 5916 II W733 Edition 1-DMA and USGS 1:50,000 Pahala, Hawaii 5916 III W733 Edition 1-DMA

Faulting and hillslope failure characterize the steep palis (cliffs) landward of the low coastal plain of Halape. Active tectonics associated with the continued eruption of Kilauea Volcano and the subsidence of its southeast flank have produced destructive earthquakes and local tsunamis in the recent past at Halape and along the entire southeast coast of Hawaii.



Kau Desert

Between Kalue and Naliikakani Point, the arid Kau Desert coast is undeveloped. A low-lying coastal terrace ranging between 1000 and 1500 ft in width northeast of Opihinehe narrows to the southwest and disappears into steep coastal cliffs at Na Puu o na Elemakule. The shoreline sits at the base of several scarps that range from 500 to 1500 ft high and that extend for several miles parallel to the coast. This coast is tectonically active. It is situated seaward of Kilauea Volcano's southwest rift zone and appears to be sliding downward and seaward. In addition to the rumblings, rockslides, landslides, and subsidence associated with the tectonic activity in the area, local earthquakes periodically generate tsunamis that impact the coast, such as those in 1868 (magnitude 4.1) and 1975 (magnitude 7.2). Facing southeast, the Kau Desert coast is protected from north swell, but is exposed to east and south swell. It is generally very dry but several streams cut across the coastal plain and periodically experience flash floods. A few small wetlands have formed behind the coastal cliffs between Opihinehe and Kaaha. Water depths increase rapidly offshore and are devoid of any significant reefs.

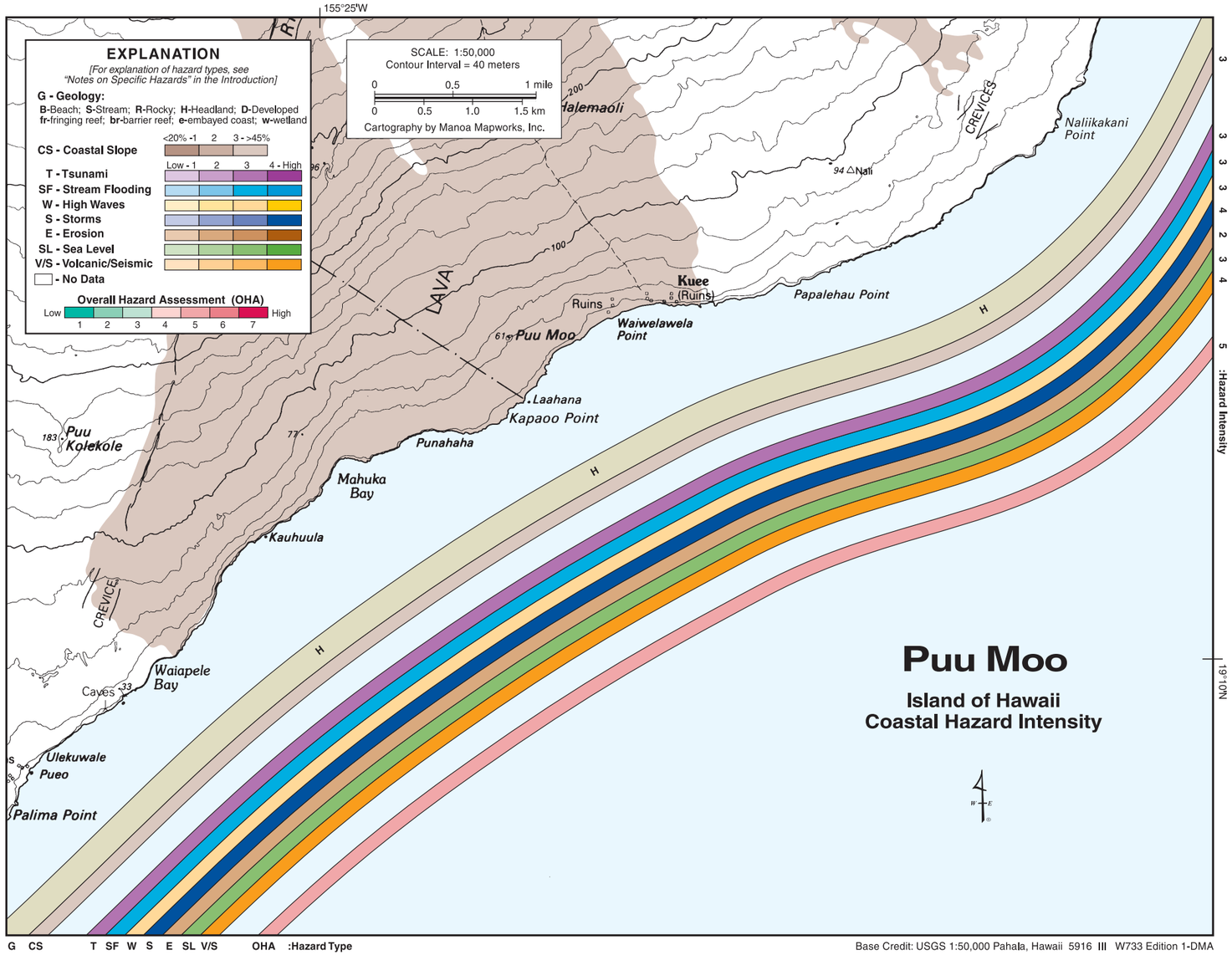
The Overall Hazard Assessment (OHA) decreases from high (6) between Kalue and Na Puu o na Elemakule to moderate to high (5) to the southwest as a result of the greater coastal slope in the west. This change in coastal slope influences the tsunami ranking which is high in the east and moderately high in the west. Stream flooding and high waves are ranked moderately high and storms are high throughout the Kau Desert Coast. Erosion is moderately low. Sea-level rise varies from high at the rocky wetlands of Kaaha and just north of Opihinehe to moderately high along the other rocky headland stretches surrounding them. The volcanic/seismic hazard is high throughout the Kau Desert coast, which lies within lava flow hazard zone 3 (Table 10, p. 24).

The Kau Desert coast is rocky, geologically young, and extremely arid. The young rock is so porous that what little rainfall reaches this region, quickly percolates below. As a result, stream channels and gulleys are rare.

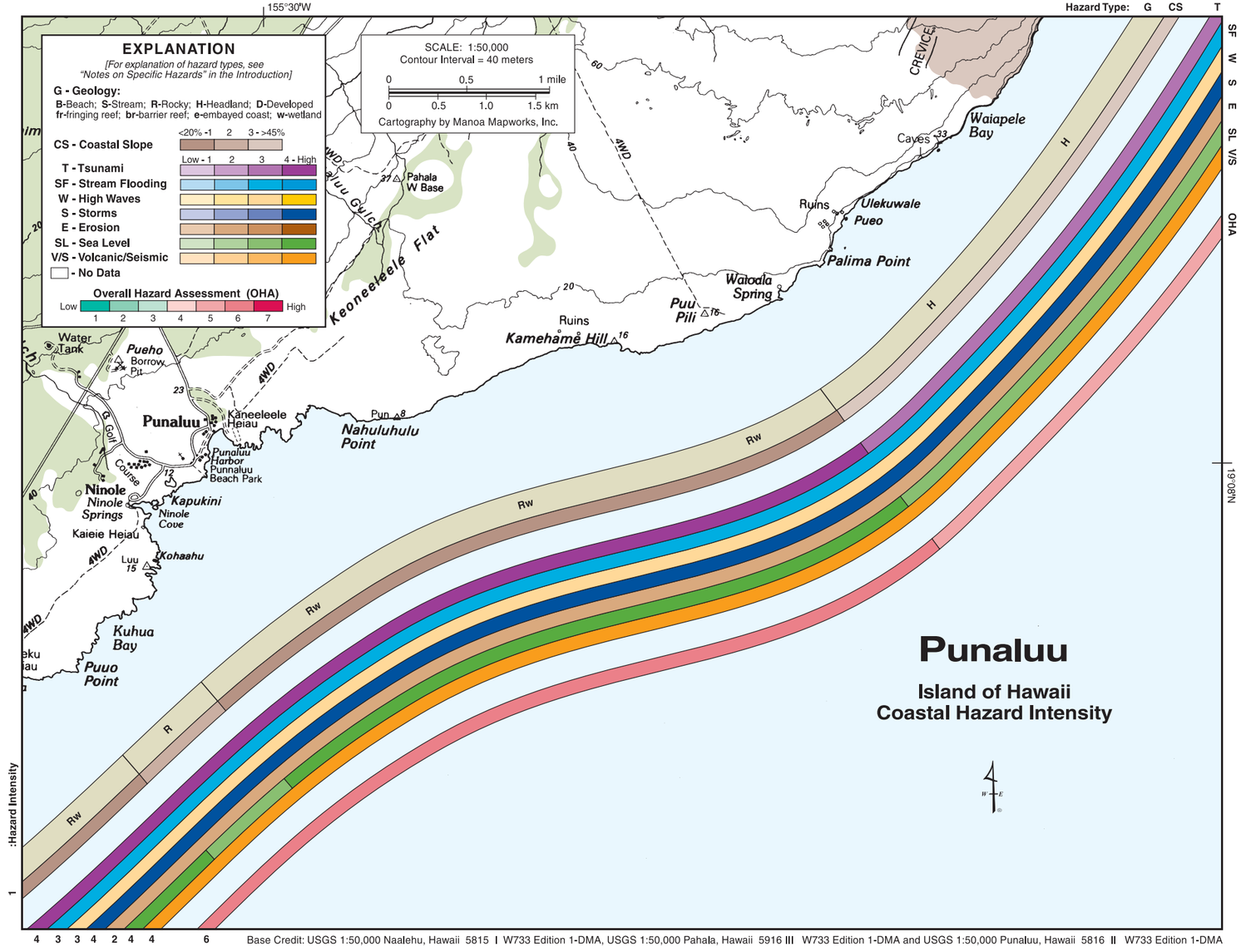
Puu Moo

Kilauea Volcano's southwest rift zone crosses the coastline near Palima Point in the Puu Moo area. The area between Waiapele Bay and Waiwelawela Point was formed during the 1823 eruption of Kilauea's southwest rift. Rugged cliffs rise between 20 and 40 ft to the hummocky tops of aa lava flows that form the gently sloping coastal terrace. Access to the water is difficult and requires traversing the rugged topography by foot or the generally turbulent seas by boat. The few beaches that exist along this coast are small, isolated, cobble beaches near the mouths of ephemeral streams. Some fresh water springs have created small wetlands and pools behind the beaches. Numerous ancient Hawaiian ruins and rock walls stand along the coastal cliffs among what appears to be an endless desert of black lava rocks. Today the entire Puu Moo coast is undeveloped.

The tsunami and high wave hazards are moderately high along the steep, rocky headland coast of Puu Moo. Despite the relatively arid climate, ephemeral streams transport large volumes of water during storms, so stream flooding is also moderately high. Facing southeast and toward approaching storms, the Puu Moo coast has a high storm hazard. Erosion is moderately low along the rocky shoreline, however sea-level rise is moderately high because of the general low slope. Puu Moo lies in lava flow hazard zone 1 (Table 10, p. 24) associated with Kilauea Volcano's southwest rift zone. As a result the volcanic/seismic threat is high. This translates into an Overall Hazard Assessment (OHA) of moderate to high (5) for the entire Puu Moo coast.



Rocky sea cliffs with small caves and arches are characteristic of the Puu Moo coast bordered by recent lava flows.



Punaluu is one of the few protected embayments along the wind-swept southeast coast of Hawaii. It is low lying with a narrow black sand and cobble beach and has experienced several destructive tsunamis.

Punaluu

Between Waiapele Bay and Palima Point, Kilauea Volcano's southwest rift dives through the coastline and under the seafloor. South of Palima Point, the Punaluu coastal zone is comprised of lavas between 500 and 1500 yr old. Steep coastal cliffs in the eastern portion of the Punaluu coast end just southwest of Palima Point, and a relatively low-lying coastal plain has developed and extends west from Puu Pili. The coast is entirely rocky except for small black sand and cobble beaches inside Punaluu Bay and Ninole Cove and at the base of Kamehame Hill. Springs feed fresh water to ponds behind the shoreline. Some of these turn brackish with high-wave overwash and tidal flushing. Punaluu has a long history as a shipping harbor and sugar plantation town. In early April 1868 however, a devastating tsunami triggered by a local earthquake leveled nearly everything along the Punaluu coast up to 18 ft above sea level. Again in April 1946, a wave associated with an Alaskan earthquake-generated tsunami ran 14 ft up the shore, clearing coastal structures and altering the shoreline morphology. Erosion due to long-term sea-level rise is also eating away at the Punaluu coastline. Flash floods periodically reshape the coast by rapidly eroding or simply burying shoreline features as they did in the winter of 1979-1980, near Ninole Springs.

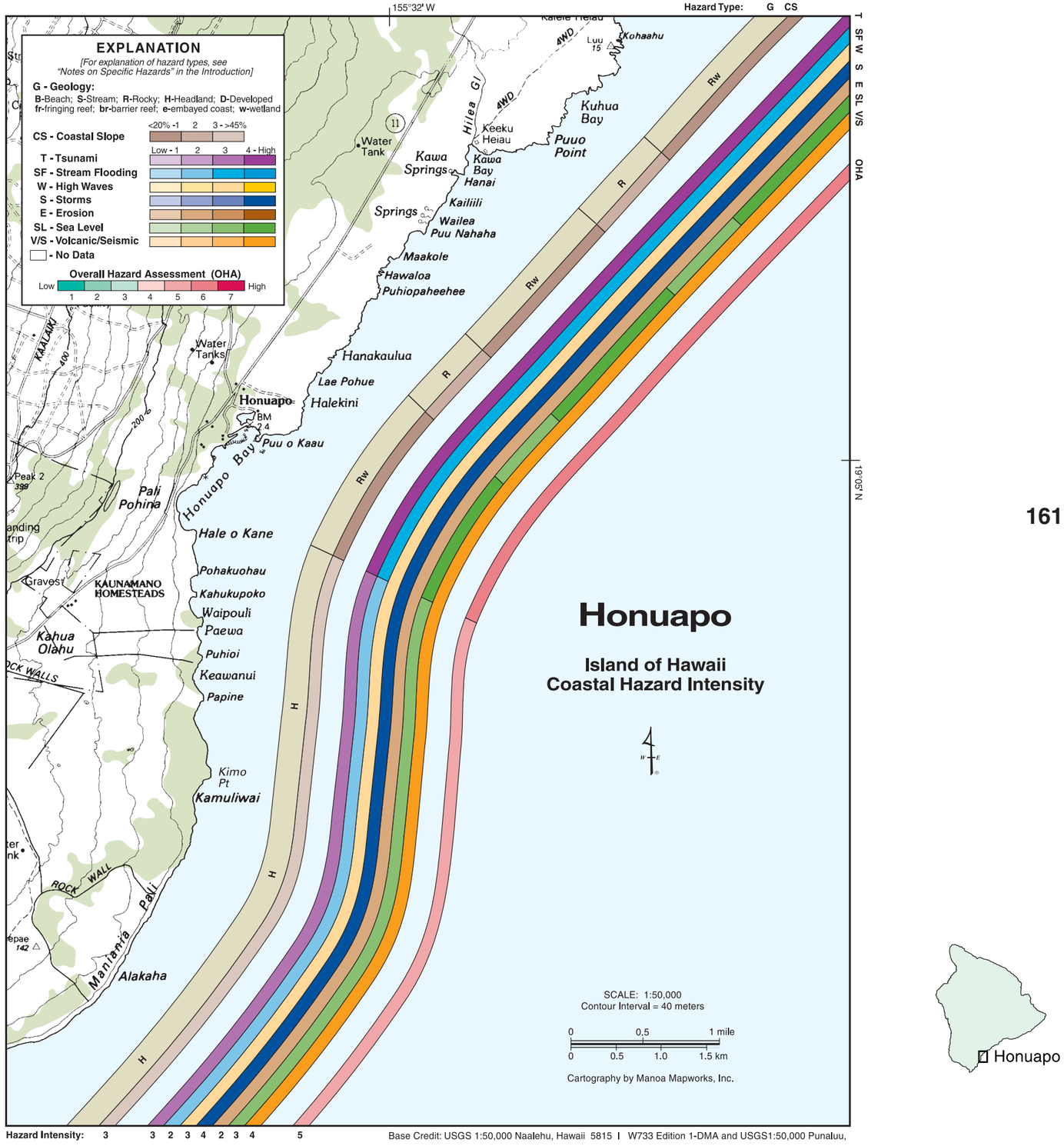
The shift in coastal slope near Puu Pili affects the magnitude and rate of inundation by waves and sea-level rise. The variation in these two hazard rankings results in a moderate to high (5) Overall Hazard Assessment (OHA) east of Puu Pili, and a high (6) Overall Hazard to the west. East of Puu Pili tsunami and sea-level rise are ranked moderately high, whereas to the west where the coast is lower they are high. An exception occurs along Puuo Point where the coast is slightly steeper than its immediate surroundings and the sea-level hazard is reduced. Stream flooding and high waves are moderately high throughout the entire region. The storm hazard is high. Erosion is moderately low, while the volcanic/seismic hazard is high along the entire Punaluu coast due to its proximity to active seismicity at Kilauea Volcano. The Punaluu coast south of Palima Point is in lava flow hazard zone 3, while northeast of Palima it is in zone 1 (Table 10, p. 24).

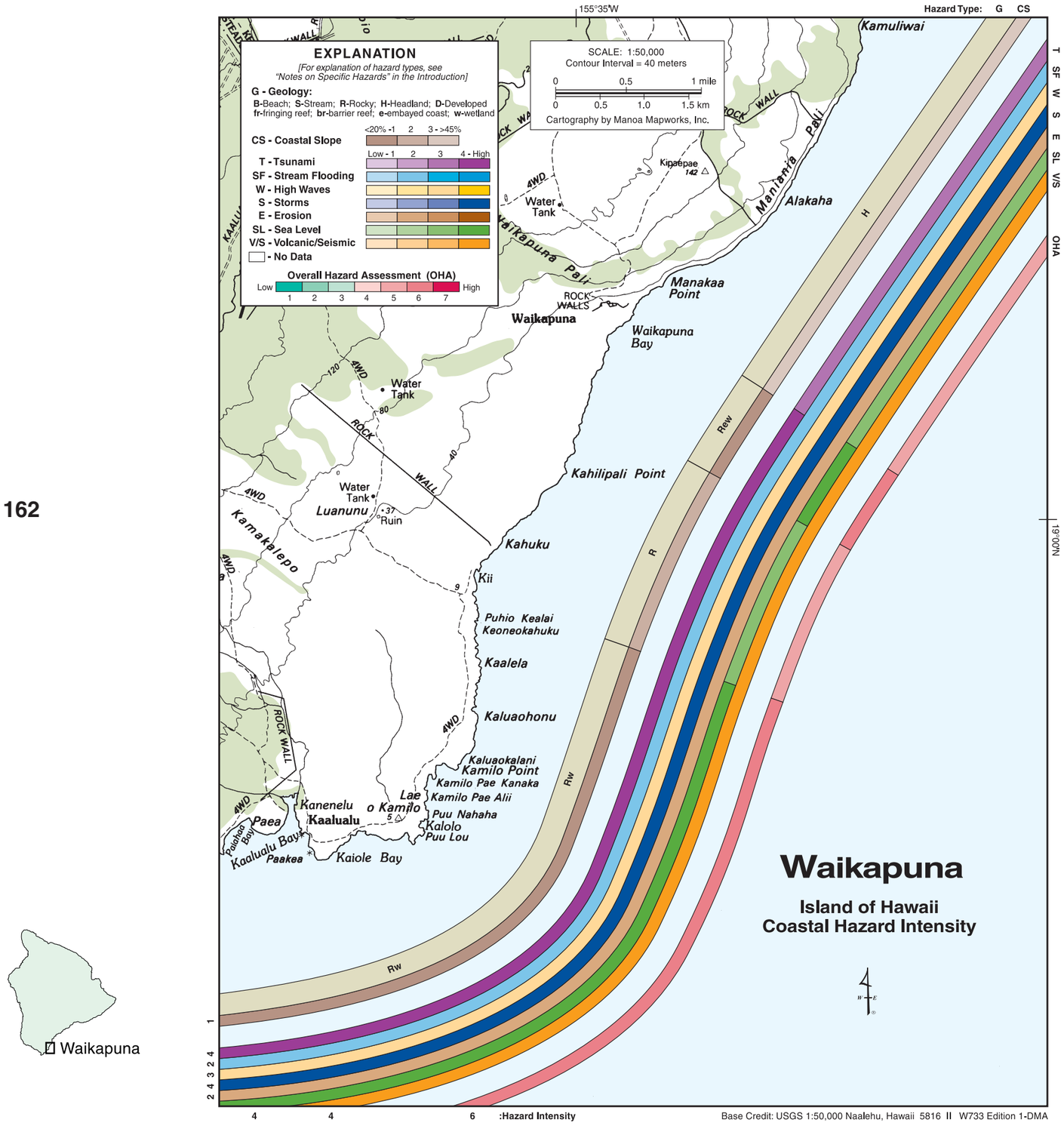
Honuapo

Between Kahua Bay and Honuapo Bay, the coast is relatively low lying and developed only with small fishing villages. South to Alakaha, the Honuapo coast is bordered by steep coastal cliffs. A few pocket cobble beaches exist near stream mouths, for example in Kawa Bay, but otherwise the coast is rocky, comprised of lavas only several thousand years old. Fresh-water springs feed wetlands at Honuapo Bay and along the coast to the north. Like most of the south coast of Hawaii, Honuapo has suffered significant damage from historical tsunamis and tectonic subsidence. The 1868 tsunami destroyed fishing villages at Kawa and Honuapo. Then the 1946 tsunami destroyed the Honuapo wharf built in 1883 for shipping and sugar transport. Facing southeast, this coast receives intense wave energy and trade-wind sea conditions prevail. Reefs are absent along this coast.

The Overall Hazard Assessment (OHA) along the Honuapo Coast is high (6) northeast of Honuapo Bay and moderate to high (5) to the southwest. This is due to the increase in coastal slope at Honuapo Bay that lessens the hazard from inundation and flooding of the coastal streams. East of Honuapo Bay, tsunami and stream flooding are ranked high and moderately high, while to the west they are reduced to moderately high and moderately low, respectively. The threat from high waves is moderately high, storm hazard is high along the entire coast, and erosion is moderately low. Sea-level rise is ranked high along the lower-lying rocky coastal segments east of Kahua Bay, between Kawa Bay and Maakole, and between Hanakaulua and Honuapo Bay. Surrounding these low-lying sections of coast the sea cliffs are steeper and as a result the sea-level-rise threat is only moderately high. The Honuapo coast is in lava flow hazard zone 3 (Table 10, p. 24). The volcanic/seismic hazard is high throughout the Honuapo region due to its proximity to seismic and volcanic activity at Kilauea Volcano.

The Honuapo coast is steep between Hale o Kane and Kimo Point (foreground) while between Honuapo and Kawa Bays the shore is comprised of a low-lying rocky coastal plain.





Waikapuna

The northeast portion of the Waikapuna coast is steep where the Maniania Pali borders the shoreline. The pali grades into a low-lying coastal plain that becomes wider at Waikapuna Bay and again at Kii. The entire shoreline is rocky with 3-10 ft high sea cliffs. It is comprised of lavas ranging between 5,000 and 10,000+ yr in age. Lavas as recent as 1868 have flowed to the coast just south of Waikapuna. A few perched beaches of loose carbonate sands exist on the coastal terrace, probably a result of wave deposition. High waves from eastern and southern swell, as well as passing storms, frequently overwash the sea cliffs making entry into the ocean difficult along this coast. Wetlands exist at Waikapuna Bay and between Kaiole Bay and Kaalela. Dunes have formed at Keoneokahuku, perhaps from the refraction of the east-northeast trade winds toward the west around this part of the island. Waikapuna is one of the most arid regions on the Big Island but intermittent streams periodically overwash during flash floods.

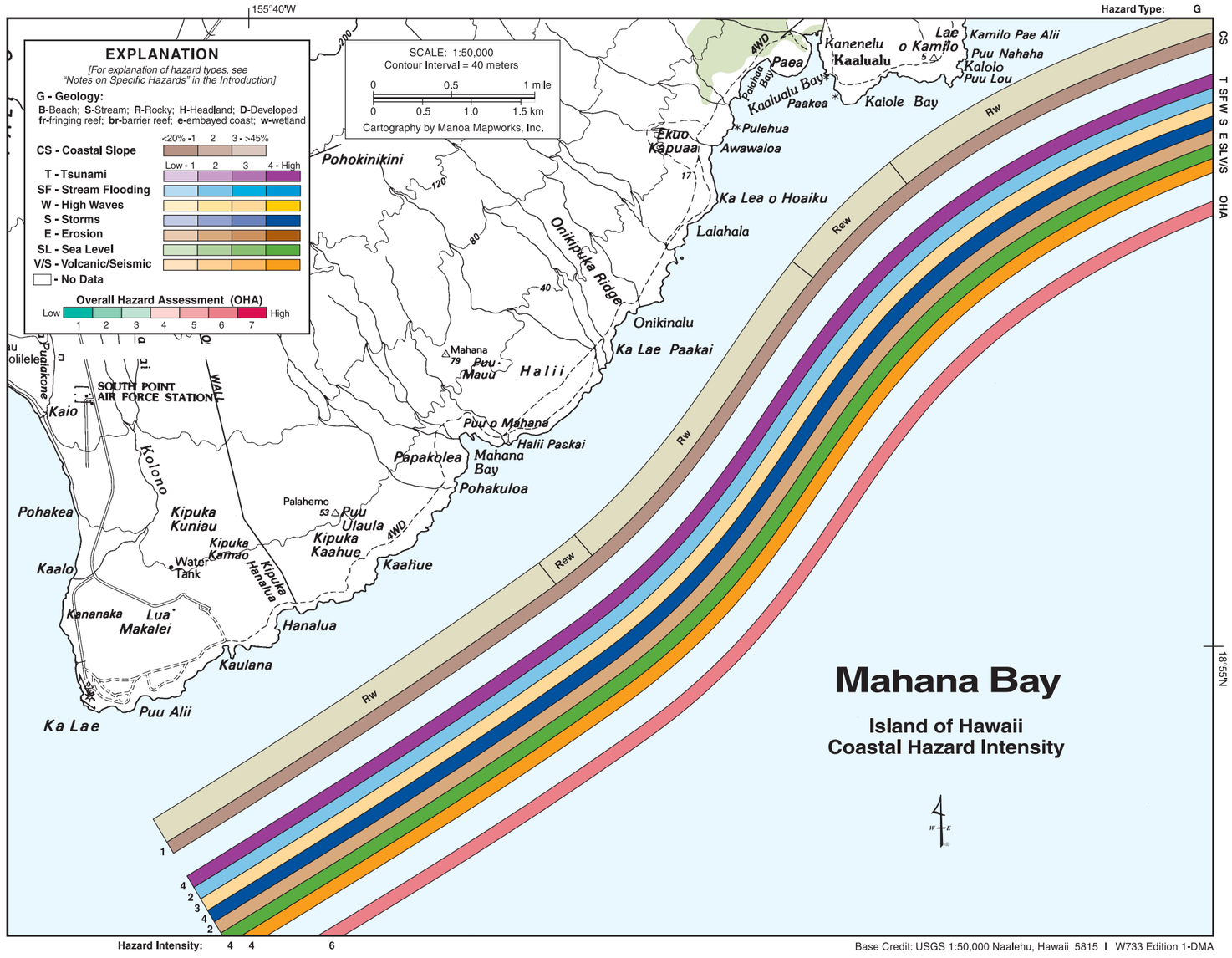
Along the Maniania Pali to Waikapuna Bay, the tsunami and sea-level rise hazard is moderately high. These two hazards are high to the southwest, except for the segment of coast between Kahilipali Point and Kii, where sea-level rise is only moderately high. Stream flooding along the entire Waikapuna coast is moderately low, while the high wave and storm hazards are moderately high and high, respectively. Erosion is only moderately low along these rocky shores. Waikapuna lies in lava flow hazard zone 6 (Table 10, p. 24). The volcanic/seismic hazard is high throughout the Waikapuna region which historically has experienced significant seismic and volcanic activity. As a result of the variation in coastal slope, the Overall Hazard Assessment (OHA) alternates from moderate to high (5) east of Waikapuna Bay to high (6) between Waikapuna Bay and just north of Kahilipali Point, and then back to moderate to high (5) along the central coast to Kii. Southwest of Kii the OHA is high (6) reflecting the low coastal slope along the Lae Kamilo region.

The undeveloped shoreline along Maniania Pali (shown here) is steep and rocky, while toward the south between Waikapuna Bay and Kamilo Point the rocky coast is low and flat.

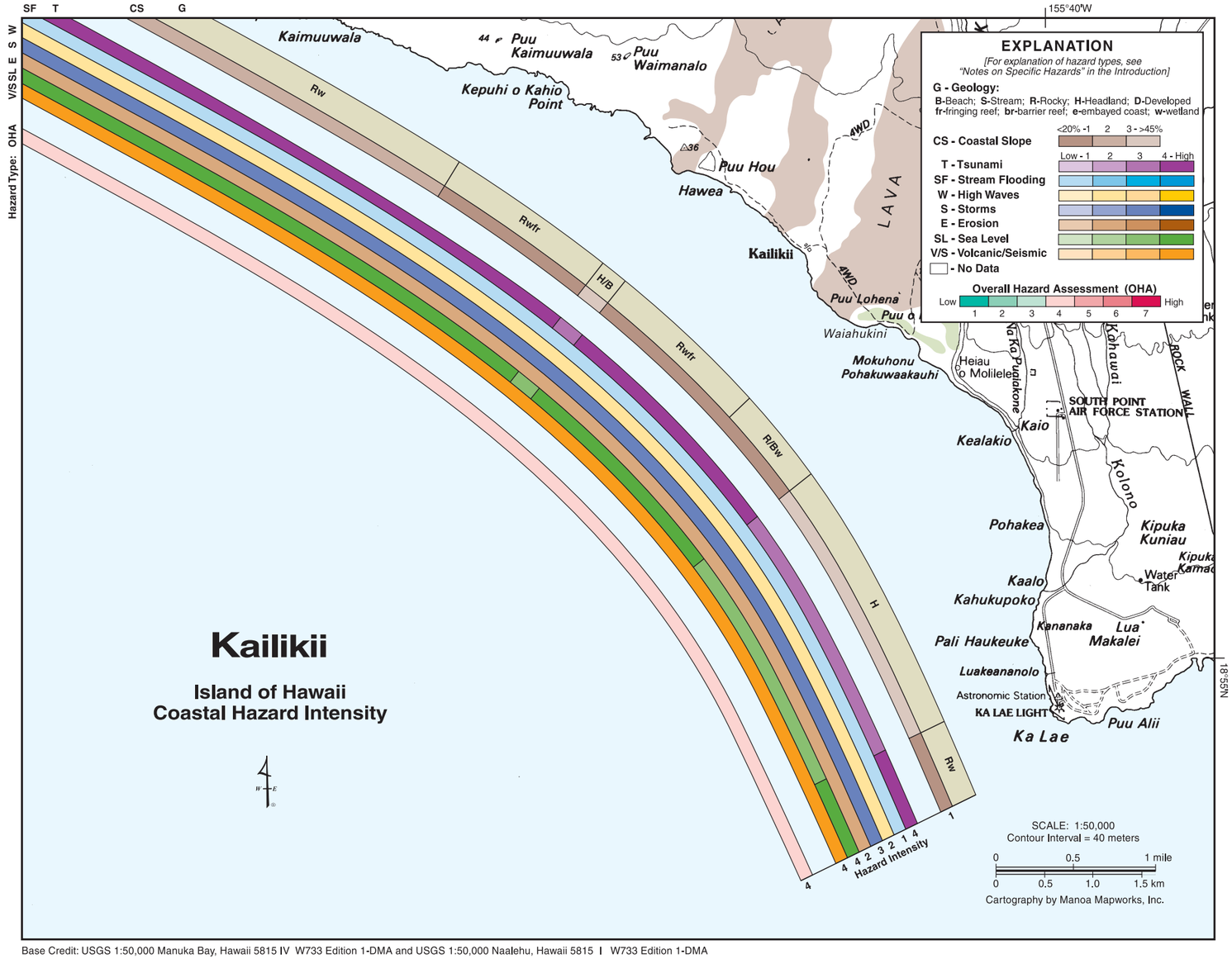
Mahana Bay

The Mahana Bay coast reaches from Kamilo to Ka Lae (South Point) the southernmost point in the 50 United States. Many small embayments line the rocky shoreline but the most notable feature along this stretch is Kaalualu Bay, an elongated waterway that reaches far inland across extensive tidal flats. It is relatively shallow and bordered by rugged aa lava flows. At the head of the bay there is a black cinder sand beach. The next bay to the south, Paiahaa Bay, has a small green sand and pebble beach. The most famous beach in this area is Papakolea, the Green Sand Beach, located in Mahana Bay. Here waves quarry the side of a volcanic cone rich in the green crystalline mineral olivine, Hawaii's most abundant mineral. Olivine is very dense and as a result is often left on beaches, while other sand components are transported away. The coast is low lying at these pocket beaches and steep cliffed in between. It is a very arid region, receiving on average less than 20 in/yr, however, there are a few intermittent streams that flow after heavy precipitation. The Mahana Bay region is highly exposed to trade winds, waves, and passing storms.

The Overall Hazard Assessment (OHA) for the Mahana Bay Coast is high (6). This is largely a result of the high tsunami, storm, sea-level rise, and volcanic/seismic rankings along this generally low coastline. Stream flooding and erosion are moderately low. The high wave hazard is moderately high along the highly exposed southern tip of Hawaii. Mahana Bay lies within lava flow hazard zone 2 (Table 10, p. 24).



Mahana Bay, famous for its green sand beach, is a small, arcuate cove set inside the remaining portion of the volcanic cone Puu o Mahana.



Base Credit: USGS 1:50,000 Manuka Bay, Hawaii 5815 IV W733 Edition 1-DMA and USGS 1:50,000 Naalehu, Hawaii 5815 I W733 Edition 1-DMA

Kailikii

The Kailikii region had lavas flowing across its coastal zone as recently as 1868. Today this area is only minimally developed. Sea cliffs ranging between 20-40 ft high near Ka Lae (South Point) terminate at Mokuhonu where a wide, low-lying coastal plain extends far inland to the headland that borders Kepuhi O Kahio Point. Small beaches are located at Waiahukini, Kailikii, and Puu Hou, and are largely green sand beaches, some with a white carbonate component. At the base of Puu Hou the beach is comprised of red sands derived from volcanic cinders. It is very arid in this region of the southern portion of the Big Island and few streams have developed west of Kahawai Kolono Stream at Kaalo. The lava rock in this area is highly porous which enables the transport of fresh water from higher elevations through the subsurface. Numerous wetlands are created when this subsurface water ponds behind the shoreline, like those near Mokuhonu, Kailikii, and Kahio. Fringing reefs become more extensive along the coast toward the western region of Kailikii.

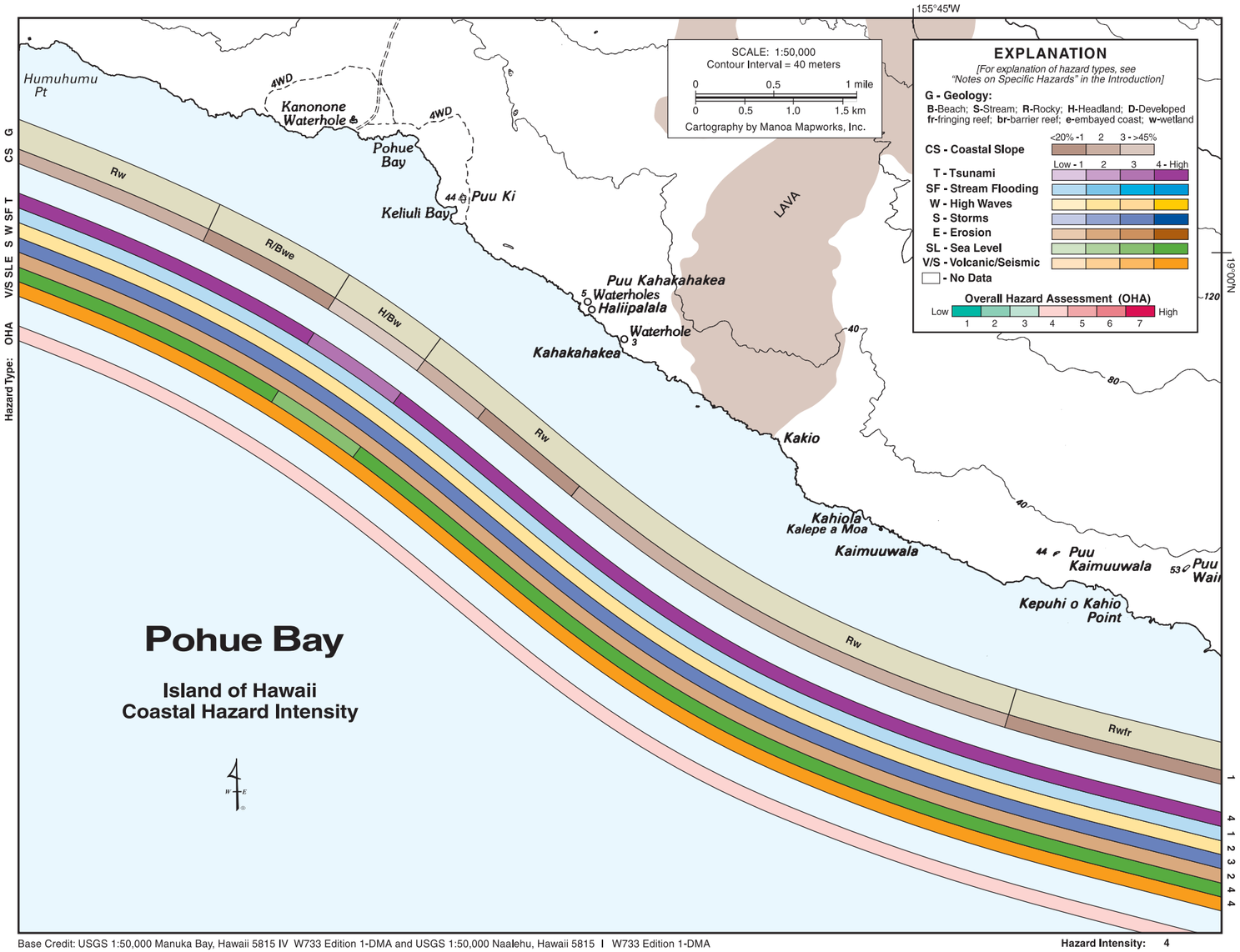
Despite variations in coastal slope that affect tsunami and sea-level rise hazards, the Overall Hazard Assessment (OHA) is moderate (4) along Kailikii. Where the coast is only 3-10 ft above sea level, between Ka Lae and Luakeananolo, Mokuhonu and Hawea, and west of Hawea, the tsunami and sea-level rise hazards are high. Along the headland segments of coast these hazards are only moderately high. Stream flooding is low on this arid coast and high waves are only moderately low because of its southwest aspect which receives only moderate south swell and Kona storm waves. Storms are ranked moderately high, because the point at Ka Lae partly protects the embayed coast from storms that primarily approach from the east and southeast. Erosion is moderately low along this rocky coast. The Kailikii coast is within lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic hazard is high due to historic volcanic activity and its proximity to seismicity associated with Kilauea Volcano.

The rocky, undeveloped coast surrounding Kailikii is situated along the base of the Pali o Kulani (right) which extends inland from Mokuhonu Pohakuwaakauhi. Kailikii is very arid and vegetation occurs only in small isolated oases where there are springs or perched groundwater.

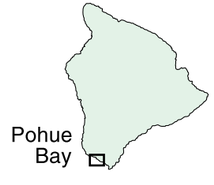
Pohue Bay

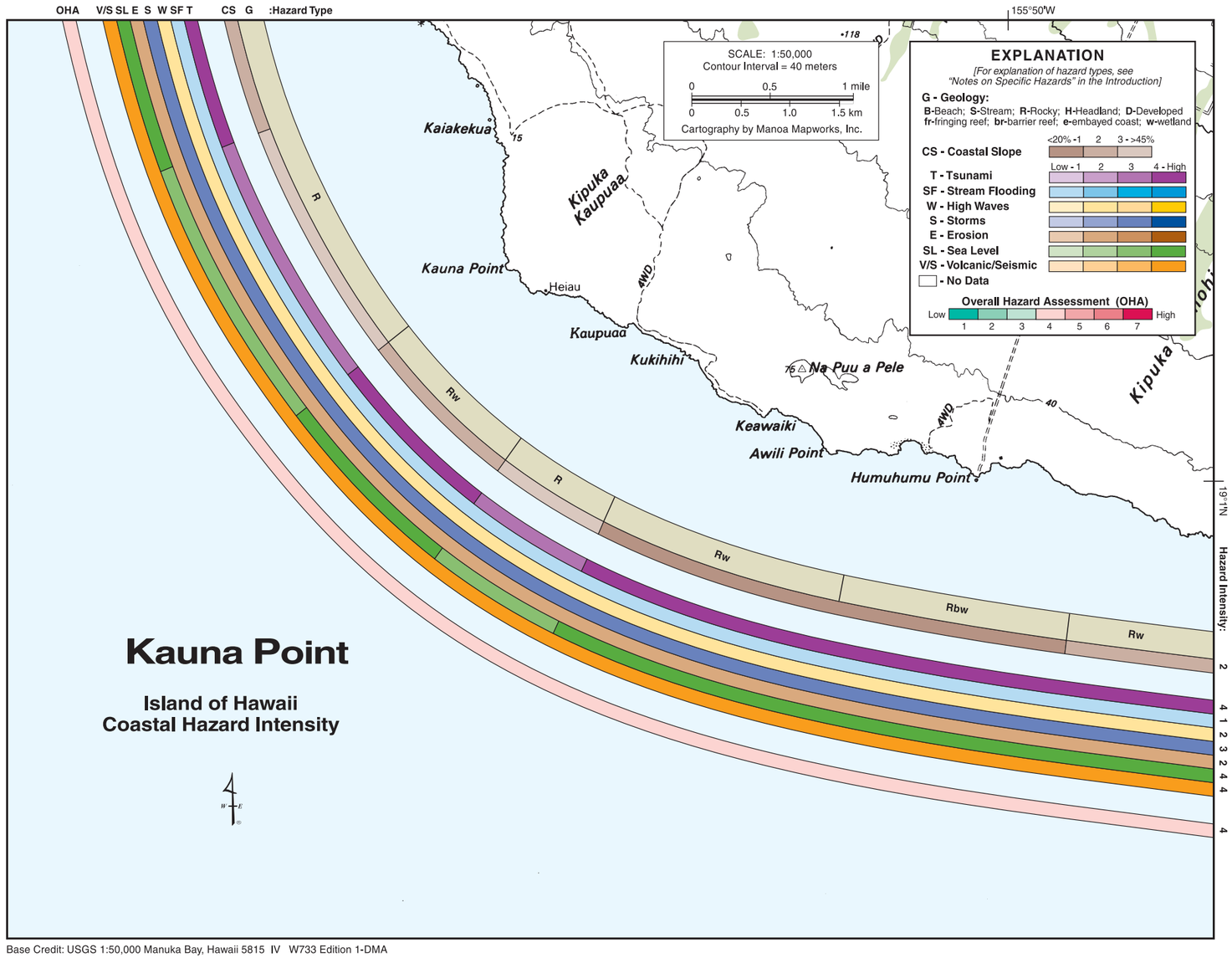
The Pohue Bay coast between Kahio and Humuhumu Point is relatively undeveloped and accessible only by boat, foot trail, or rugged 4-wheel drive vehicle. Sea cliffs ranging between 15-30 ft high border a rather wide coastal plain that slopes gently seaward, except for cinder cones that protrude through its surface. In 1887, lavas erupted from Mauna Loa Volcano's southwest rift and flowed across the coastal slopes to the coast between Kakio and Kahakahakea. The entire coast is rocky with isolated beaches deposited by storms just above the sea cliffs. A white carbonate sand beach lies inside Pohue Bay. Despite the aridity of the Pohue Bay coast, several wetlands have formed where water has ponded behind the shoreline. A small fringing reef extends along the southern portion of the area seaward of Kepuhi o Kahio Point.

The tsunami hazard along the Pohue Bay coast is high except for the headland at Keliuli Bay, where it is reduced to moderately high because of the steeper slopes. Stream flooding is low in this arid region. High waves are moderately low because only moderate wave heights associated with south swell and Kona storm waves annually reach these shores. The storm hazard is moderately high. Erosion is moderately low along this rocky sea-cliffed coast. The sea-level threat is high for the entire coast except for the headland at Keliuli Bay. The Pohue Bay coast lies in lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic hazard is high for the Pohue Bay coast as it is for all of Hawaii Island due to active seismicity and volcanism at Kilauea Volcano. These rankings translate to a moderate (4) Overall Hazard Assessment (OHA) for the Pohue Bay coast.



Much of the coast around Pohue Bay is rocky and low lying except for occasional bluffs and small sea-cliffs formed by remnant volcanic cones, like Puu Ki near Keliuli Bay (shown here), and old lava flows.





Base Credit: USGS 1:50,000 Manuka Bay, Hawaii 5815 IV W733 Edition 1-DMA

Kauna Point

Between Kaiakekua and Humuhumu Point the Kauna Point coast is undeveloped and largely rocky. Sea cliffs of lava rock are steeper west of Kukihihi. Awili and Humuhumu Points have small volcanic cinder beaches. The lavas that form the Kauna Point coast flowed as recently as 750 yr ago. Kauna is arid and few streams flow to the sea in this area. Instead, fresh water flows from the hillsides to the sea through underground (subsurface) crevices and voids in the highly porous lava rock. Wetlands occur at Kauna, Awili, and Humuhumu Points where this water has ponded behind the shoreline. Offshore the seafloor is mostly rocky with some carbonate sands in small sand fields or pockets.

The Overall Hazard Assessment (OHA) for Kauna Point is moderate (4). Despite this uniform ranking, the tsunami and sea-level hazards vary between high along most of the Kauna Point coast to only moderately high between Kaiakekua and Kauna Point and between Kaupuaa and Kukihihi. Stream flooding is low because of the region's extreme aridity, while high waves that generally arrive from the south and with Kona storms are moderately low. Storms are ranked moderately high and erosion along the rocky Kauna Point coast is moderately low. Kauna Point is located in lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic threat is high along the Kaua Point coast due to historical volcanic activity and high seismicity associated with volcanism at Kilauea Volcano.

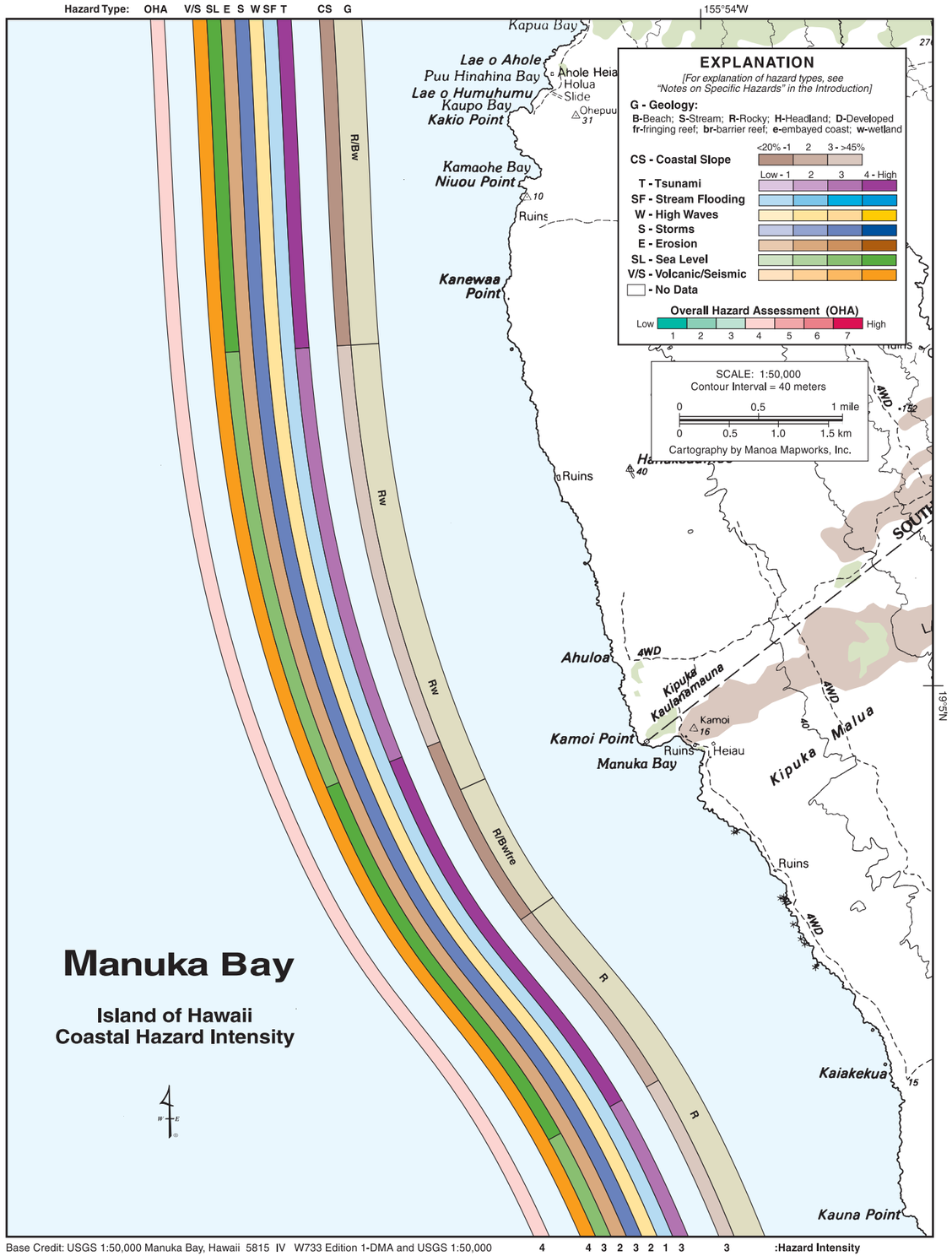
The rocky and rugged Kauna Point coast is low lying and undeveloped, formed of old aa lava flows.

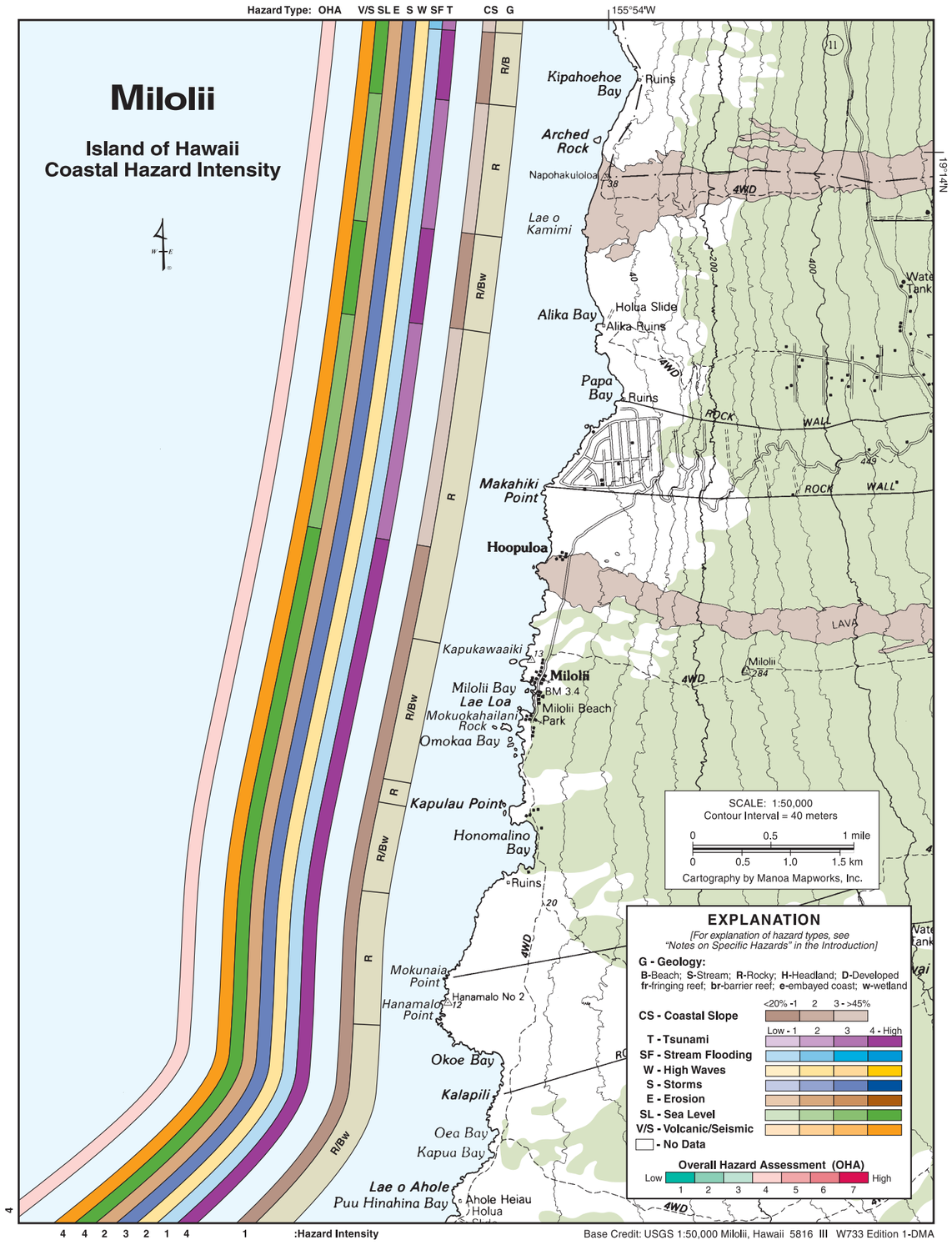
Manuka Bay

The rocky Manuka Bay coast extends between Lae o Ahole and Kauna Point. Between Ahuloa and Kanewaa Point, the coast steepens slightly from an otherwise low-lying coastal plain. While it is largely undeveloped today, the area used to be home to a large population of Hawaiian fisherman as evidenced by the many heiau (temples) and petroglyphs in the area. Narrow perched beaches occur along the rocky shore and a mixture of coral rubble, white carbonate sand, and volcanic fragments form the beaches at Manuka and Kakio Point. This part of southwestern Hawaii is situated in the lee of Mauna Loa Volcano and as a result is very arid. Few streams flow across the coast near Manuka Bay. Wetlands have formed, however, just landward of the shoreline where water flowing underground accumulates. A small fringing reef has developed at Manuka Bay. The rest of the coast has only small patch reefs. The seafloor offshore is largely rocky with small discontinuous sand fields.

The tsunami and sea-level hazards are high except south of Kaiakekua and between Ahuloa and Kanewaa where they are only moderately high because of the steeper coastal slopes. In this arid portion of Hawaii, stream flooding is low. High waves are ranked moderately low because of the moderate wave heights that reach this southwest-facing coast. Storms are a moderately high hazard because tropical cyclones commonly pass the south and west sides of the islands. Erosion is moderately low along the rocky Manuka Bay coast. Manuka Bay lies in lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic hazard is high along the Manuka Bay coast due to recent volcanism in the area and its proximity to seismic activity associated with eruptions of Kilauea Volcano. The Overall Hazard Assessment (OHA) for the Manuka Bay coast is moderate (4).

Recent lava flows from Mauna Loa Volcano have added new ground to various portions of the coast surrounding Manuka Bay. The Manuka Bay region is undeveloped, arid, and relatively low sloping.





Milolii

Between Kipahoehoe Bay and Kapua Bay the Milolii coast has seen active volcanism this century. Lava flows associated with the 1919 and 1926 eruptions of Mauna Loa Volcano covered the coastline at Hoopuloa and Lae o Kamimi. Between Kapua Bay and Hoopuloa the coast is low and slopes gently seaward. North of Hoopuloa, the coast is higher and steeper except for Alika Bay and Kipahoehoe Bay which are relatively low lying. Numerous small rock islets and submerged rocks lie offshore of Milolii and Omokaa Bays. Small beaches of black volcanic and white calcareous sand occur at Kapua, Oea, Okoe, Honomalino, Milolii, Alika, and Kipahoehoe Bays. The Hoopuloa beach is largely comprised of pebbles and coral cobbles. Sea-level rise has had dramatic impacts on the beaches along this coast. Between 1940 and 1980, the shoreline at Honomalino beach moved 200-300 ft landward. Small wetlands exist at Kapua, Honomalino, Milolii, and Alika Bays. Lying in the rain shadow of Mauna Loa, the Milolii coast is dry and few streams have developed amidst the geologically young, porous lava fields. Only small patch reefs exist along this shore. Periodically, large wave events quarry the reefs and throw their rubble debris atop the coastal cliffs to form perched beaches.

The Overall Hazard Assessment (OHA) for the Milolii region is moderate (4). The tsunami hazard varies from high south of Hoopuloa, between Alika Bay and Lae o Kamimi, and north of Arched Rock to moderately high between Arched Rock and Lae o Kamimi and between Papa Bay and Hoopulua. Stream flooding is low throughout the region. High waves are only a moderately low threat where annual wave heights from south swell are generally only 1-4 ft. Storms are ranked moderately high because Milolii faces west toward approaching Kona Storms and the typical track of passing tropical cyclones. The rocky coast is relatively effective at withstanding denudation, so erosion is moderately low. Sea level is rising fast relative to the land, so it is ranked high in the low-lying segments south of Hoopuloa, between Alika Bay and Lae o Kamimi, and north of Arched Rock. It is moderately high along the steeper coast from Arched Rock to Lae o Kamimi and between Papa Bay and Hoopulua. Milolii lies in lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic hazard is high along the Milolii coast due to recent volcanism and significant seismicity associated with eruptions of Kilauea Volcano.

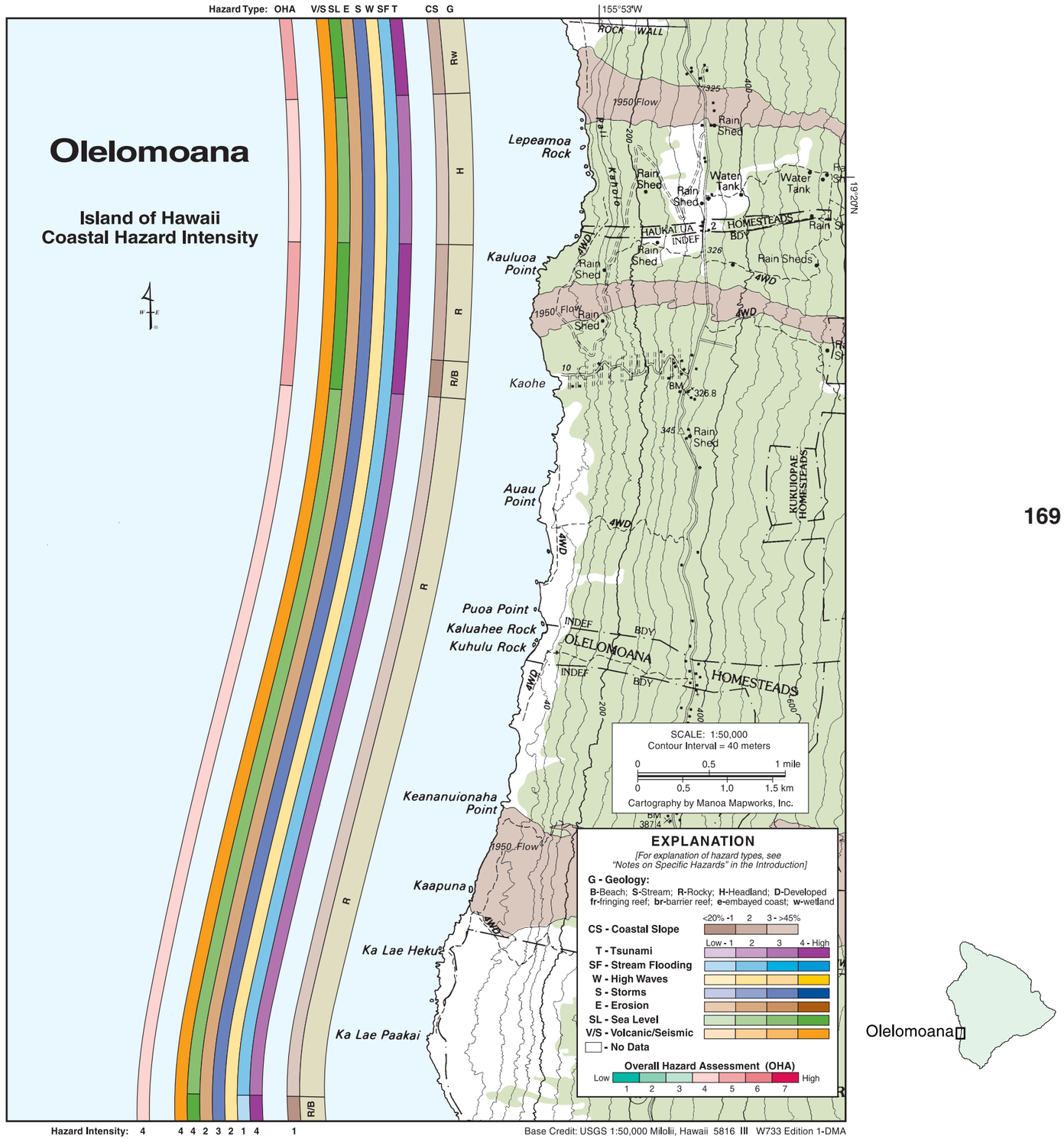
Irregular erosional remnants in the form of sea stacks and rocks as well as submerged toes of recent lava flows have produced scenic tidepools and shallow, rocky coastlines in the vicinity of Milolii.

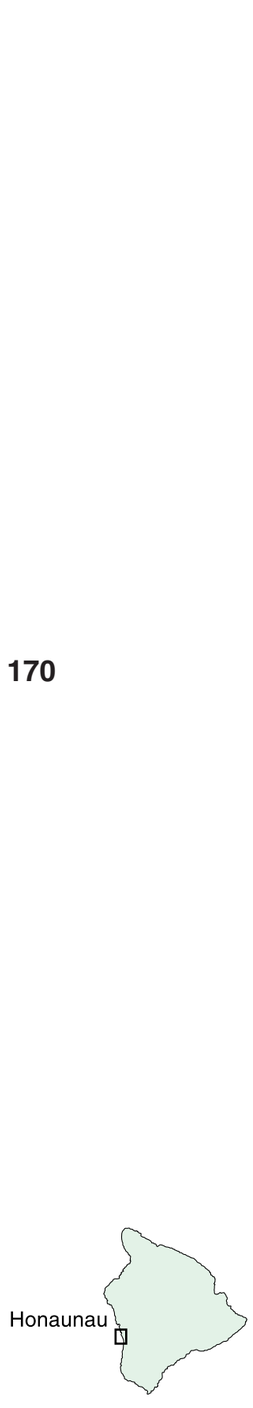
Olelomoana

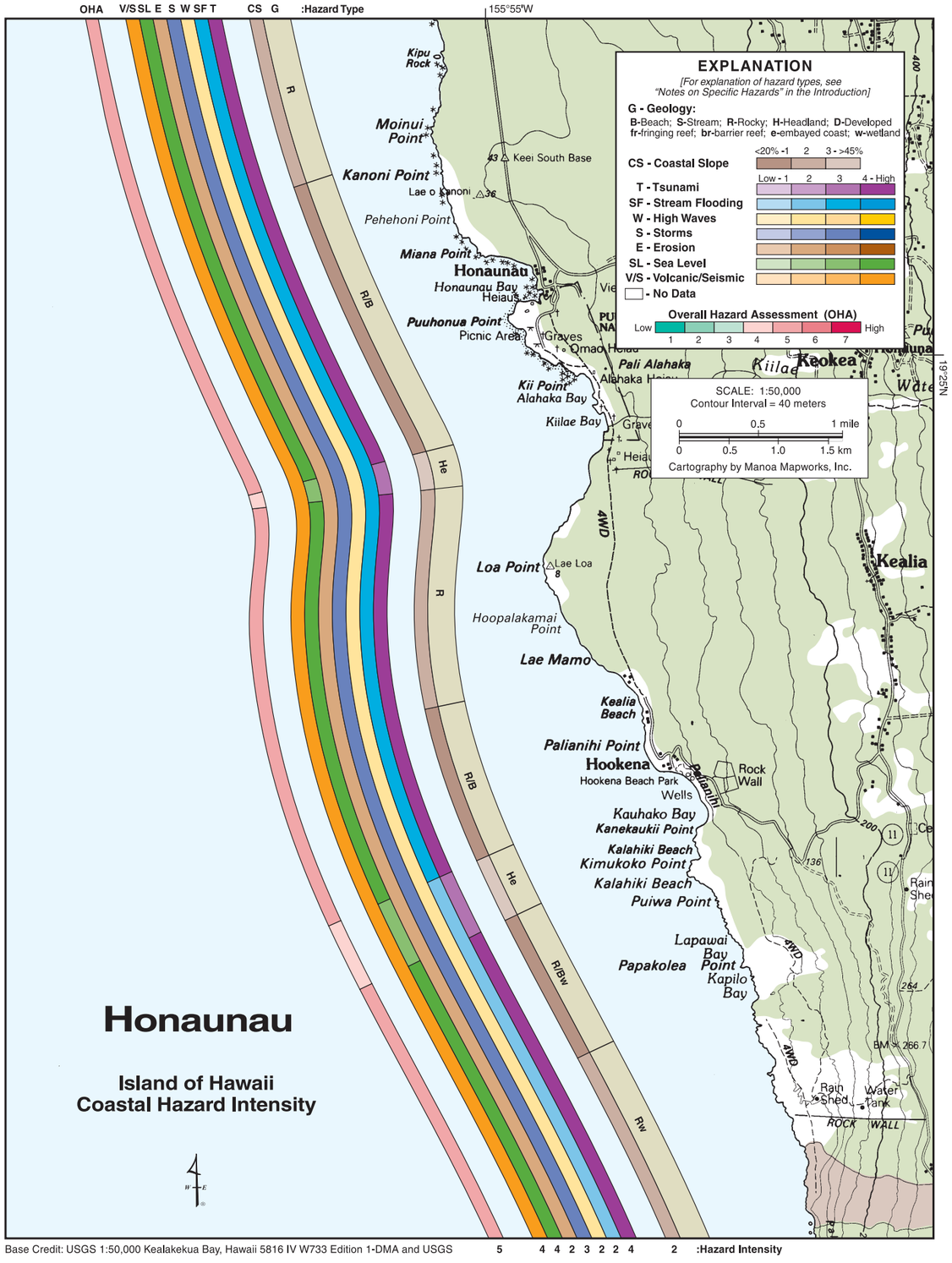
The Olelomoana coast extending between Ka Lae Paakai in the south to Lepeamoa Rock in the north is largely undeveloped except for the Kauluoa Point region. The coast gently slopes between Kauluoa Point and the pebble beach of Kaohe, otherwise the region is mostly steep with sea cliffs. Small coves have formed along the shoreline, partly due to erosion and partly the result of deposition from lava flows extending the shoreline seaward. Many small rock islets (sea stacks) lie offshore. Lava flows as recent as 1950 reached the sea at Kaapuna, just south of Kauluoa Point, and north of Lepeamoa Rock. The southwest coast of Hawaii along Olelomoana receives slightly more precipitation than the region to the south. Small patch reefs have developed along the older volcanic portions of this coast.

The Overall Hazard Assessment (OHA) of Olelomoana primarily reflects the variation in tsunami and sea-level threats to the lower coastal slopes. Between Kauluoa Point and Kaohe the OHA is moderate to high (5) where tsunami and sea level are ranked high. To either side, where the coast is steeper, the OHA is moderate (4) and tsunami and sea level are both moderately high. North of Lepeamoa Rock, the coast again is low lying and tsunami and sea level threats are increased to high, resulting in an OHA rating of moderate to high (5). Stream flooding is moderately low north of Ka Lae Paakai. Throughout the entire region the high wave and storm hazards are moderately low and moderately high, respectively. Erosion is moderately low along the rocky shores of Olelomoana, while the volcanic/seismic threat is high due to recent volcanic activity along this stretch of coast and seismicity associated with Kilauea Volcano. The Olelomoana coast lies in lava flow hazard zone 2 (Table 10, p. 24).

Mauna Loa lava flows as recent as those from 1950 have cut across the moderate sloping and rocky coast along Olelomoana Homesteads and Kahoe.







Honaunau

The Honaunau coast is developed near Hookena and Honaunau amidst beautiful rocky embayments with small cobble and sand beaches. A low, wide bench of lava rock extends along Kealia Beach and Honaunau with steeper sea cliffs in between. Generally, calm wind and wave conditions prevail, but high waves and Kona storms have left their mark by depositing coral rubble as a debris line or storm beach atop the low volcanic coastal cliffs throughout this region. Numerous tide pools have formed along the lava bench at Puuhonua Point and Honaunau Bay. This is also the site of the famous and restored Puuhonua o Honaunau National Historic Park, the City of Refuge as it used to be called. Patch reefs are well developed at Honaunau Bay and near Kalahiki Beach. Fresh water seeps occur offshore, evidence that a significant amount of fresh water is transported to the sea through the subsurface. Hookena, to the south, harbored an important interisland steamer landing for over 50 years until high waves and storms in the 1930's eventually destroyed the landing.

The Overall Hazard Assessment (OHA) for Honaunau varies between moderate to high (5) and moderate (4). Along the majority of this low-lying, gently-sloping coast the OHA is moderate to high (5) because of the high tsunami and sea-level hazards. Only at the two headlands of Kauhako and Kiilae Bays are the tsunami and sea-level threats reduced to moderately high, and as a result the OHA is also reduced to moderate (4). Stream flooding is moderately low south of Hookena and moderately high to the north, where more streams make their way to the shoreline. The high wave hazard along this and most southwest-facing shores of Hawaii is moderately low. Storms, however, are moderately high as they tend to track to the west when they pass the islands. Erosion is moderately low along the rocky sea cliffs. Honaunau lies within lava flow hazard zone 2 (Table 10, p. 24). The volcanic/seismic hazard is high due to the seismicity associated with eruptions of Kilauea Volcano.

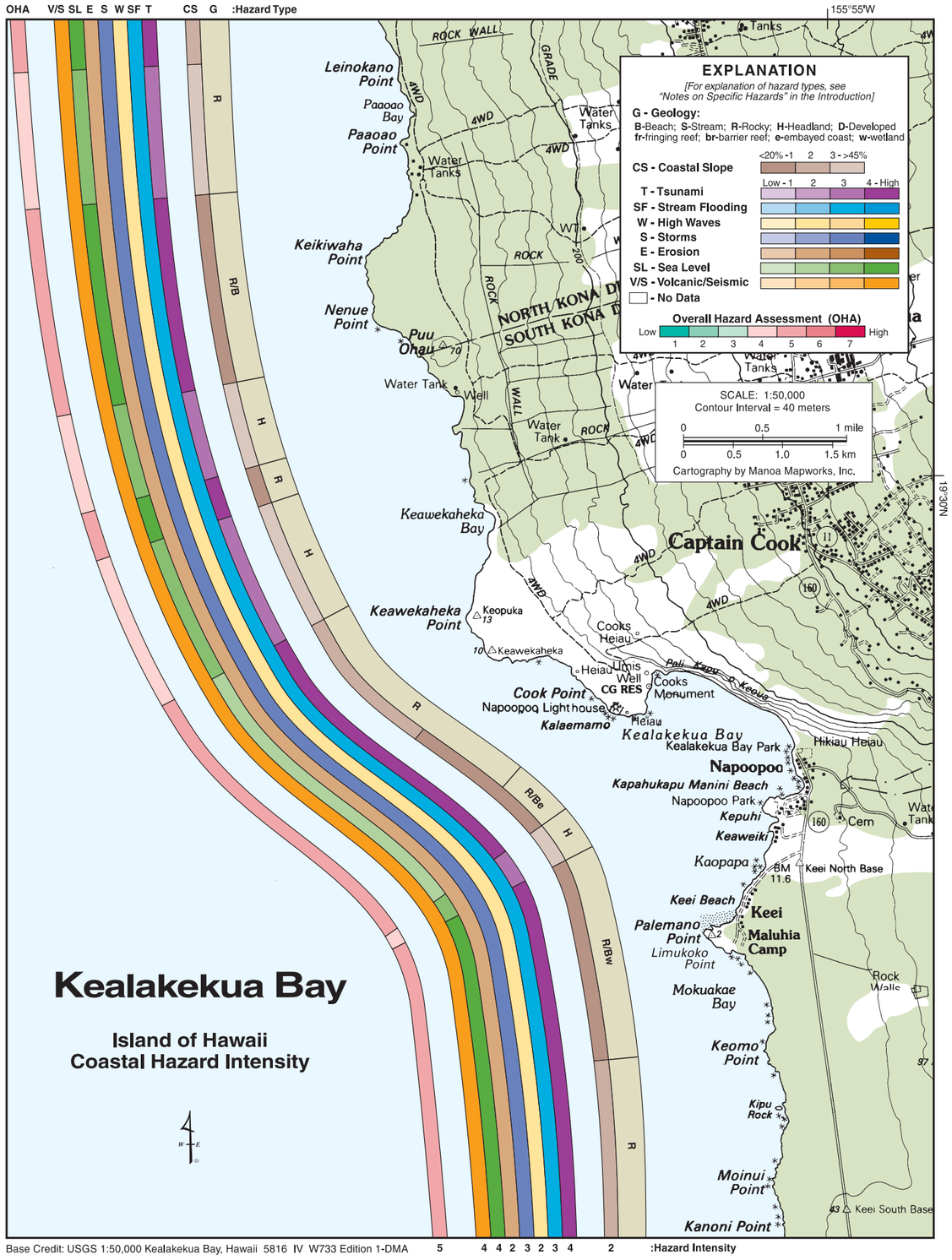
The rocky coast of Honaunau is composed of Mauna Loa lava flows ranging between 1000 and 2000 yr old. The steeper coastal slope south of Hookena gives way to a low-lying rocky coast in the vicinity of Honaunau, the City of Refuge.

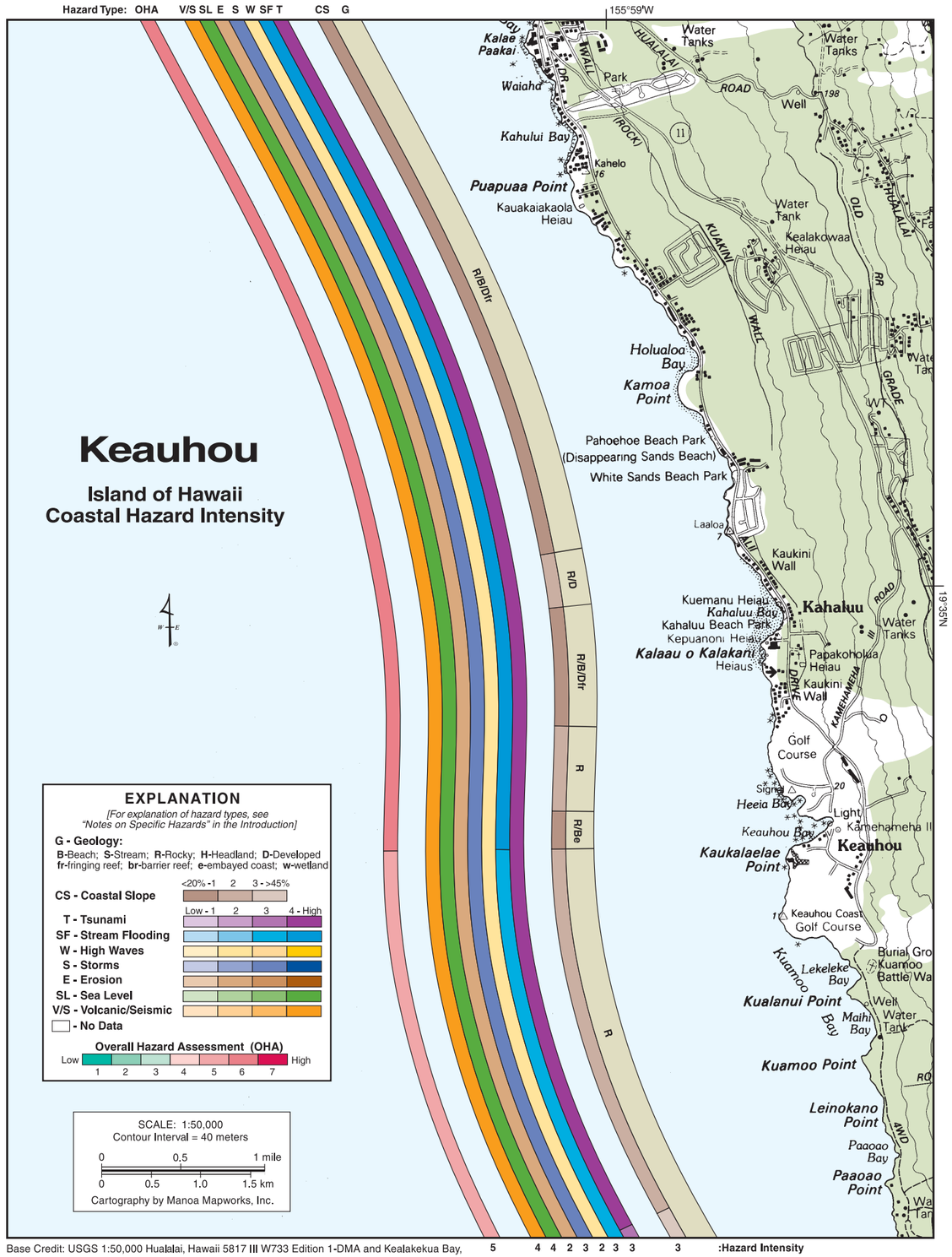
Kealakekua Bay

The Kealakekua Bay coast is lower lying and more gently sloping south of Napoopoo than to the north. This is primarily a rocky coast with headlands along Pali Kapu o Keoua, Keawekaheka Bay, Puu Ohau, and Paaoao Point. The Kealakekua embayment is the most notable feature along this coast and it protects a small pebble and cobble beach. White sand beaches exist at Keei and at Napoopoo, although they appear to have narrowed considerably in recent years. Storm beaches of cobbles and pebbles are strewn atop some of the rocky points and benches. Keei is historically significant for being the battle site for Kamehameha I's first attempt to gain control of the Big Island. Kealakekua is also famous for being the site where Captain Cook was killed in early 1779. Despite extensive reef growth, Kealakekua Bay periodically receives large waves that scour the bottom. In 1959, Hurricane Dot moved large boulders onshore and covered the pre-existing beach. Runup from the 1868 locally generated tsunami reached 45 ft in this bay.

The Overall Hazard Assessment (OHA) along the Kealakekua Bay coast varies systematically from moderate to high (5) along the low-lying segments to moderate (4) at the steeper headlands at Paaoao Point, Puu Ohau, Keawekaheka Bay, and the Pali Kapu o Keoua. Where the coast is low lying and more vulnerable to inundation by tsunami and sea level, these hazards are high. Along the headlands, tsunami and sea level are ranked moderately high. Stream flooding is moderately high throughout this entire coast. High waves are moderately low, while storms are moderately high. Erosion is moderately low along the largely rocky Kealakekua Bay coast. The southern section of Kealakekua Bay lies in lava flow hazard zone 3, while north of Paaoao Point the coast is within lava flow hazard zone 4 (Table 10, p. 24). The volcanic/seismic hazard is high along this coast which is seismically active due to its proximity to Kilauea Volcano.

Much of the Kealakekua Bay coast is rocky and low lying, except for the steep headland of Pali Kapu o Keoua fronting the northern end of the bay near Cooks Monument.





Keauhou

Keauhou

The highly developed Keauhou Coast curves around the scenic embayments of Paaoao, Maihi, Lekeleke, Keauhou, Kahaluu, Holualoa, and Kahului Bays. Most of this coast is rocky, composed of 10,000 yr old lavas. To protect development at the shoreline from wave overwash and flooding, many seawalls have been erected along the rocky shore. Small beaches occur at Keauhou and Kahaluu Bays and along portions of the coast between Kamoa Point and Waiaha; most appear to have narrowed in the recent past. Gentle slopes predominate except for small steep rocky outcrops north of Heeia Bay and at Laaloa. Several small fringing reefs have developed around Kalaau o Kalani and Puapuaa Points. Streams transport runoff from the relatively steep southwest face of Hualalai Volcano which receives on average fifty to sixty inches of rainfall each year. Amidst the sprawling urban development are numerous Hawaiian archaeological artifacts and ruins that attest to Keauhou's occupation in ancient times.

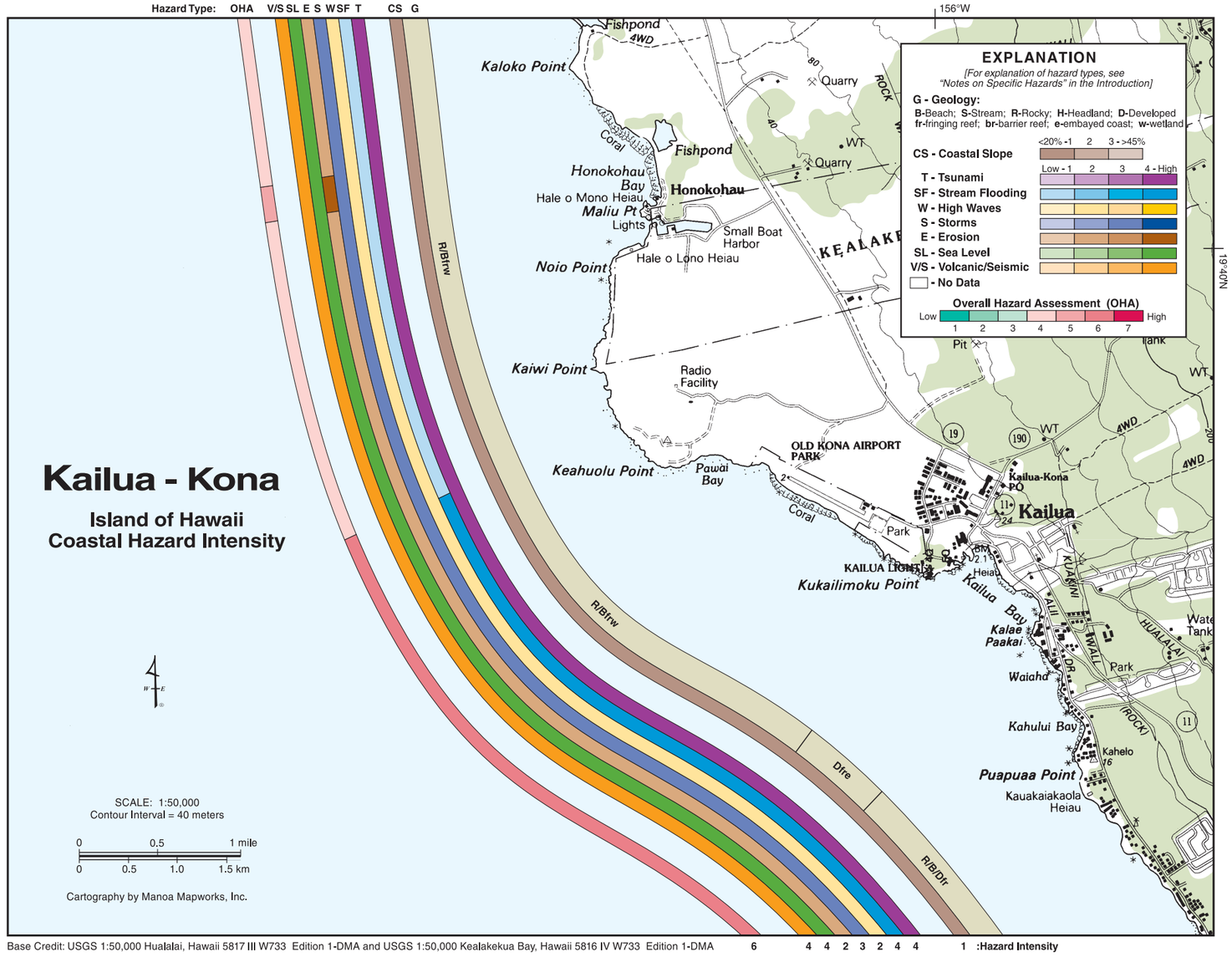
The generally low-lying Keauhou coast is vulnerable to marine overwash and inundation, so the tsunami and sea-level hazards are high. The increase in precipitation and runoff north of Kaukalaelae Point results in a high ranking for stream flooding to the north of that point and a moderately high hazard to the south. High waves are only a moderately low threat along this southwest-facing coast. Storms are moderately high, while erosion is moderately low. The volcanic/seismic hazard is high in Keauhou due to the high seismicity of the area associated with volcanic processes of Mauna Loa and Kilauea Volcanos, as well as the ever present threat of an eruption of Hualalai Volcano. The Keauhou coast lies in lava flow hazard zone 4 (Table 10, p. 24). The increase in the stream-flooding hazard north of Kaukalaelae Point results in an increase in the Overall Hazard Assessment (OHA) from moderate to high (5) south of that point, to high (6) north of Kaukalaelae Point along Alii Drive through Kahaluu and into southern Kailua-Kona to the north (see Kailua-Kona map).

The Keauhou coast is characterized by small coves and embayments separated by 10 to 15 ft tall rocky headlands. Considerable development focused on tourism has occurred around Keauhou during the past several decades despite annual high wave overwash of Alii Drive and the ever-present threat of a Hualalai Volcano eruption or tropical storm impact.

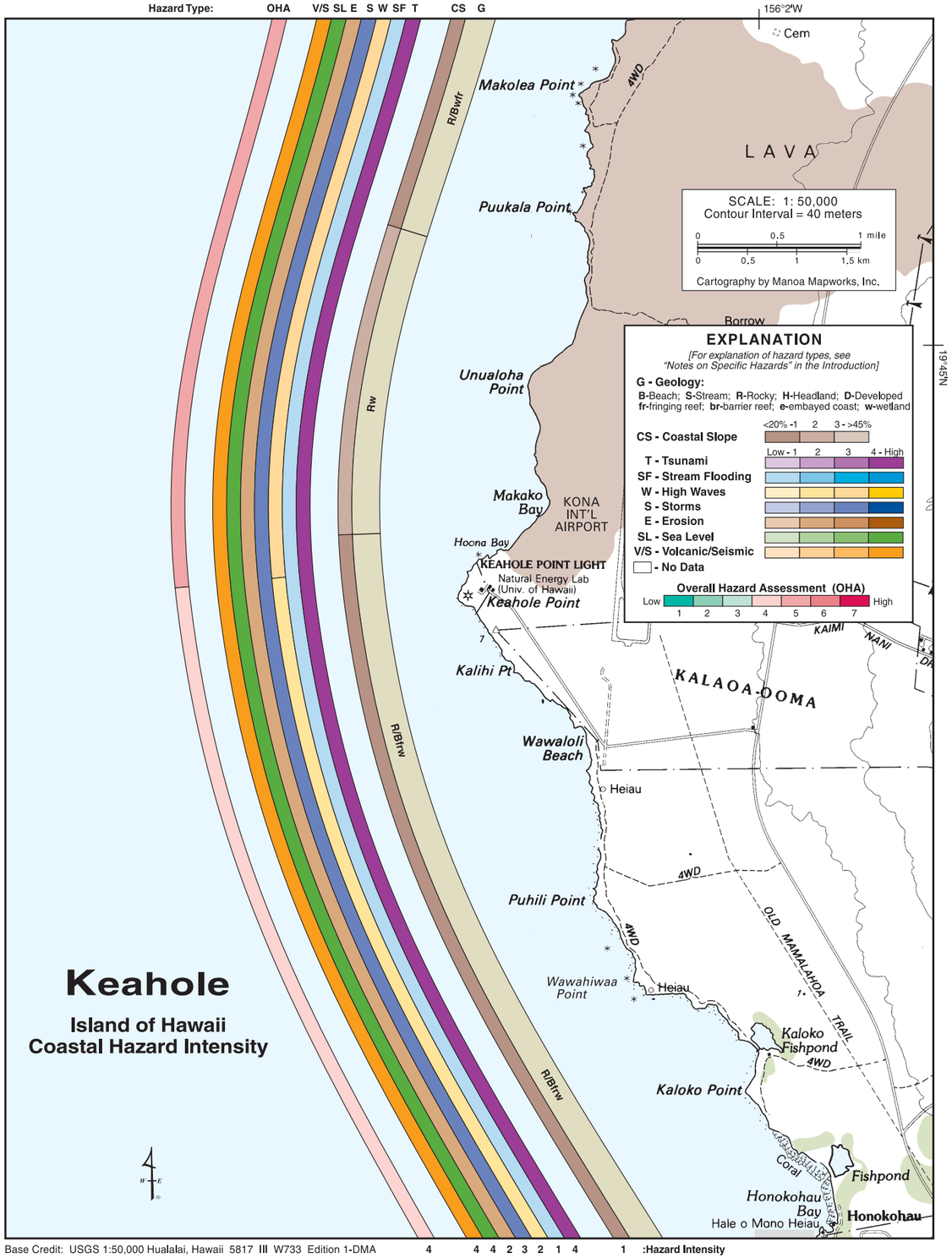
Kailua-Kona

The Kailua-Kona region is extensively developed along its rocky waterfront. Kailua Bay cuts into 12,000 yr old volcanic rocks, whereas the region between Kukailimoku and Kaloko Points is a constructional coastal plain comprised of 2000 yr old lavas. Many coastal streams incise the older rocks south of Keahuolo Point whereas few streams exist to the north. The presence of a wetland at Honokohau Bay is evidence that fresh water flows below ground before ponding behind the shoreline. Fringing reefs extend along the entire Kailua-Kona coast. Few beaches are found within this coastal region. Just north of the pier in Kailua Bay, is a small and sheltered beach, which was the last home of King Kamehameha I. It is protected by pahoehoe rocks and reefs offshore. Several small pocket beaches exist within Kailua Bay and at the entrance to the Honokohau small boat harbor. Storm deposited rubble forms beaches perched atop the low rocky coast between Kukailimoku Point and Honokohau Bay. Despite the generally rocky shoreline, numerous seawalls have been erected to protect development along Kailua-Kona's Alii Drive from marine overwash, flooding, and coastal erosion.

The Overall Hazard Assessment (OHA) for the Kailua-Kona coast is high (6) south of Keahuolu Point and moderate (4) to the north due to the difference in the coastal flooding hazard. A portion of Honokohau Bay that is experiencing erosion has an OHA of moderate to high (5). The tsunami hazard is high along the low coast. The potential for stream flooding is high south of Keahuolu Point but low to the north where streams mostly flow through the subsurface rocks. Although high waves periodically overwash Alii Drive, the high wave hazard is moderately low because of Kailua-Kona's exposure to low to moderate wave heights associated with south swell. The storm hazard is moderately high because this coast faces directly toward oncoming Kona storms. Erosion is moderately low along this rocky coast, except at the beach of Honokohau Bay, where it is moderately high. The threat of sea-level rise is high, because of relatively rapid island subsidence in addition to global sea-level rise. Kailua-Kona lies in lava flow hazard zone 4 (Table 10, p. 24). The volcanic/seismic threat is high due to geologically recent volcanic eruptions and high seismicity.



The city front of Kailua–Kona is set within the deeply embayed coast of Kailua Bay, on a narrow, low-lying coastal terrace. Near-annual high wave overwash of Alii Drive causes power outages and flooding, while the high rate of relative sea-level rise enables greater wave energy to erode the already vulnerable, developed shoreline.



Keahole

Island of Hawaii
Coastal Hazard Intensity

Base Credit: USGS 1:50,000 Hualalai, Hawaii 5817 III W733 Edition 1-DMA 4 4 4 2 3 2 1 4 1 :Hazard Intensity

The Keahole coast is very arid, low lying, and only slightly developed. The University of Hawaii's Natural Energy Laboratory and the Kona International Airport are located amidst lava flows only a couple of thousand years old. In 1801, lava flowed to the sea just north of the airport, building Unualoha, Puukala, and Makolea Points seaward. Storm beaches of white calcareous and black volcanic sands are perched atop this generally rocky shoreline with many protected small tide pools at the water's edge. Small rock remnants exist offshore of a small embayed beach and wetland just south of Makolea Point. Fishponds, wetlands, and heiau (ancient temples) are common. A fringing reef extends along most of this coast.

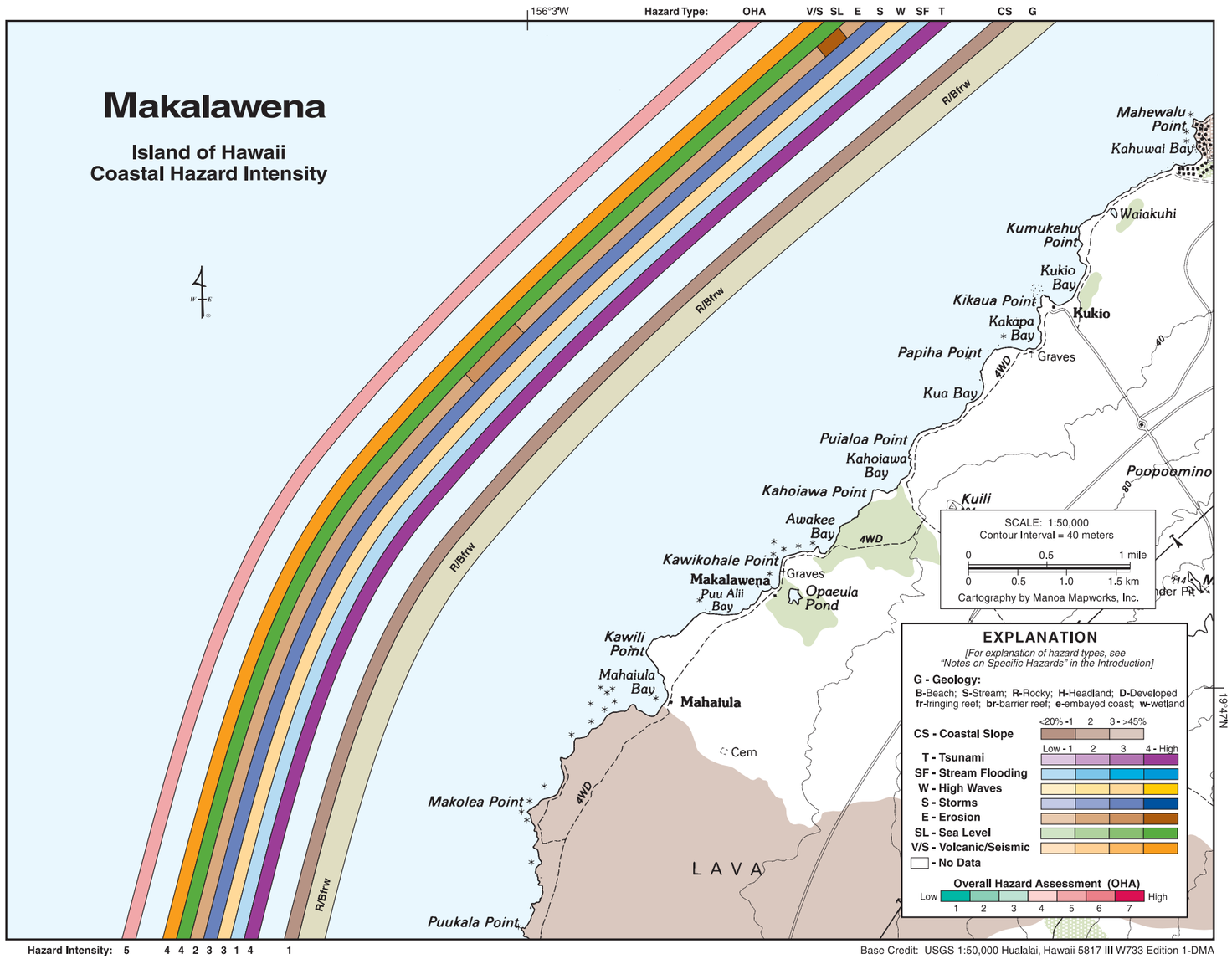
The Overall Hazard Assessment (OHA) for the Keahole coast reflects the change in high wave hazard at Keahole Point, the western-most point on the Island of Hawaii. To the south, the coast faces southwest and primarily receives south and southwest swell, so the high wave threat is only moderately low and the OHA is moderate (4). North of Keahole Point, the coast faces west-northwest and receives higher west swell, so the high wave hazard is moderately high and the OHA is moderate to high (5). The tsunami hazard is high while stream flooding is low along the entire Keahole coast. Storms are ranked moderately high along this coast that is exposed to Kona storms and the primary track of tropical cyclones to the west. Erosion is moderately low along this rocky coast, while the threat of sea-level rise is high due to active subsidence of the area. The Keahole coast lies in lava flow hazard zone 4 (Table 10, p. 24). However, because of historical volcanic flows in the area and its proximity to high seismicity associated with volcanic processes of Mauna Loa and Kilauea Volcanos, the volcanic/seismic hazard is high along the Keahole coast.

The rocky and arid coast of Keahole is low lying and developed with industry, including the University of Hawaii's Natural Energy Lab and the Kona International Airport.

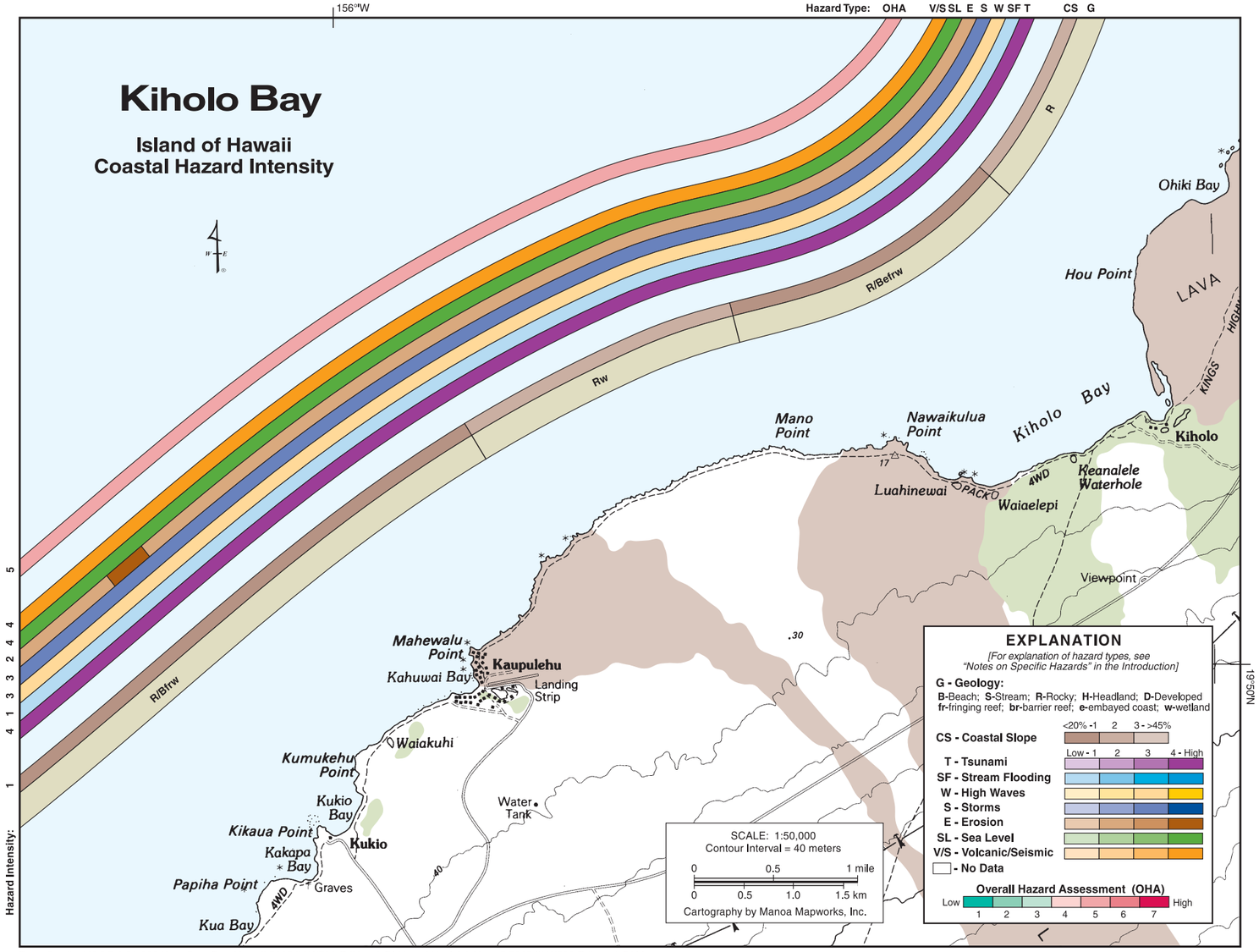
Makalawena

The Makalawena coast, stretching between Makolea Point and Kukio Bay, is comprised of lava flows ranging from 200 to 5000 yr in age. The coastal zone is low lying and mostly rocky. Sandy beaches have formed in the small embayments of Mahaiula, Makalawena, Kahoiawa, Kua, and Kukio, with narrow strips of storm rubble surrounding them. This coast is undeveloped today but was used in ancient times as evidenced by the large Opaeula fish pond and ruins in the area. Wetlands line the shore as well as numerous vegetated sand dunes. Narrow fringing reefs are present off-shore of this western-most portion of the Big Island.

The tsunami hazard is high along this low-lying coast, while stream flooding is low due to the extreme aridity and lack of surface stream flow. High waves are moderately high here where the coast faces toward approaching west and northwest swell. The storm hazard is moderately high also. Erosion is moderately low except at Makalawena, where it is moderately high, and at Kukio Bay where it is high. Sea-level rise is high along this and all of the Big Island, where global sea-level rise is occurring in addition to land subsidence. The volcanic/seismic threat is high due to the active volcanism and high tectonic activity on the Big Island. Makalawena lies in lava flow hazard zone 4 (Table 10, p. 24). This translates into a moderate to high (5) Overall Hazard Assessment (OHA) for the Makalawena coast.



Rocky embayments and small points formed by Holocene lava flows from Hualalai Volcano line the arid and low-lying Makalawena coast.



Base Credit: USGS 1:50,000 Kawaihae Bay, Hawaii 5817 IV W733 Edition 1-DMA and Hualalai, Hawaii 5817 III W733 Edition 1-DMA

Kiholo Bay

The rocky Kiholo Bay coastline, extending between Kukio Bay in the south and Hou Point in the north, is composed of lava flows of various ages. Lava that emanated from Hualalai Volcano in 1800-1801 extended the shoreline seaward just north of Mahewalu Point and at Nawaikulua Point, covering older rocks ranging from 1500 to 3000 yr in age. In 1859, lava flowed over 30 mi from the north flanks of Mauna Loa and created Hou Point. A large sand and boulder spit abuts the southern boundary of this 1859 flow and partly encloses a 5-acre lagoon at Kiholo. The lagoon is shallow and carbonate sands line the bottom. The stark contrast of black basalt rock surrounding a brilliant aqua-blue lagoon, creates a beautiful sight on a sunny day. Moderately steep headlands have formed just north of Hou Point and for a 1 mi stretch of coast south of Mano Point; otherwise the coast is low lying. Few residential homes exist, but several old archaeological sites remain. Tide pools, wetlands, and black and white sand beaches line the shoreline along the small coves in the south and Kiholo Bay in the north. A fringing reef is well developed along most of the coast except seaward of Mano Point. It is very arid on this coast.

The Overall Hazard Assessment (OHA) is moderate to high (5) reflecting high tsunami, sea-level, and volcanic/seismic hazards. Stream flooding is low because of extreme aridity and lack of surface runoff; most fresh water flows through the porous rock below the surface. High waves are ranked moderately high along this coast that faces west-northwest and receives moderate wave heights from west and northwest swell. Storms are moderately high here because Kona storms and tropical cyclones, that often track west of the Big Island, send moderate winds and waves into the Kiholo Bay region. At Kiholo the lava flow hazard zone in this region shifts from 4 in the south associated with Hualalai volcanics, to 3 in the north where Mauna Loa volcanics have been more active in historic time (Table 10, p. 24).

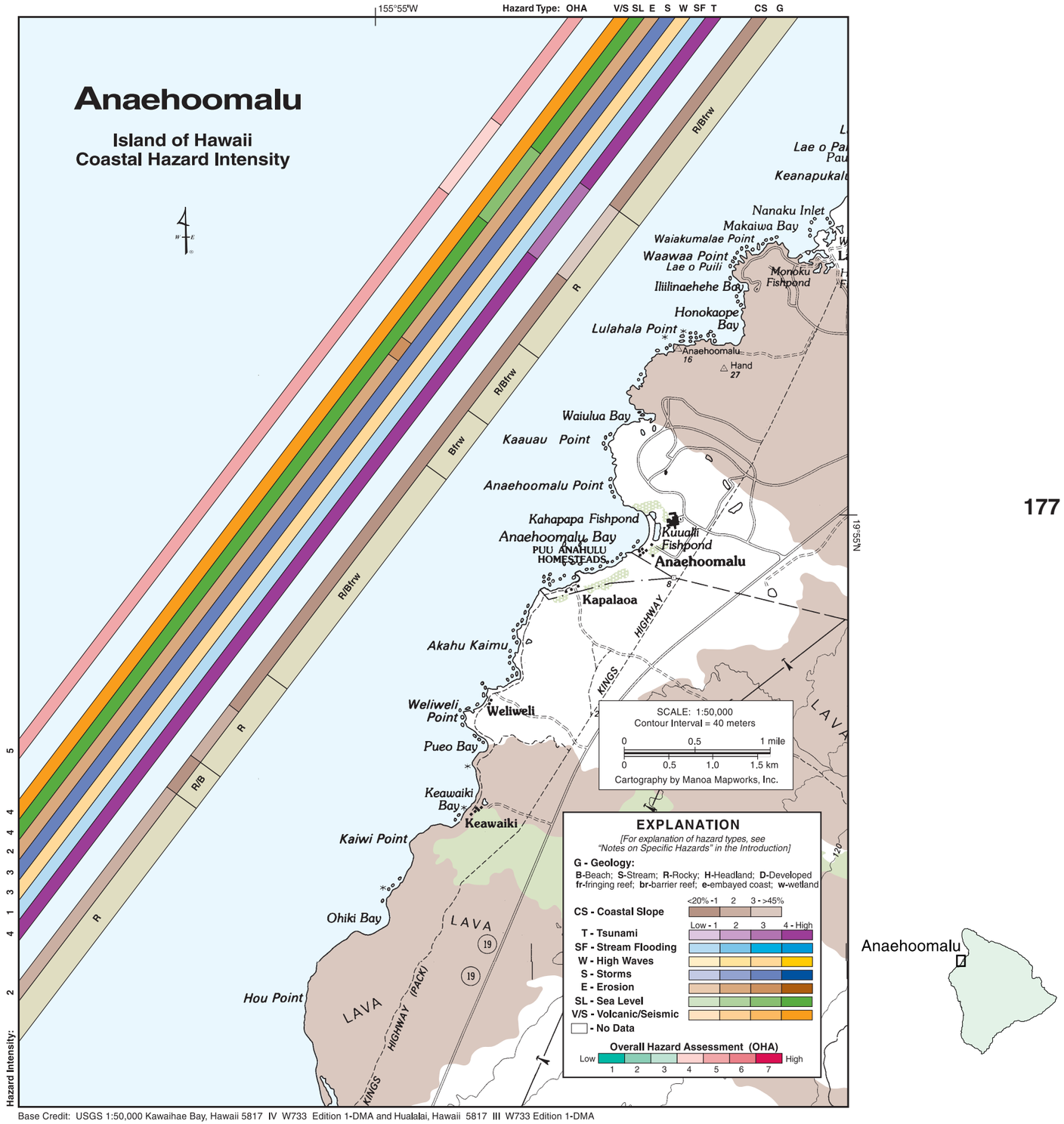
Lava flows from Hualalai and Mauna Loa eruptions in 1800 and 1859 traveled up to 30 mi to reach the sea around Kiholo, helping to form the beautiful embayment and the rocky points surrounding it.

Anaehoomalu

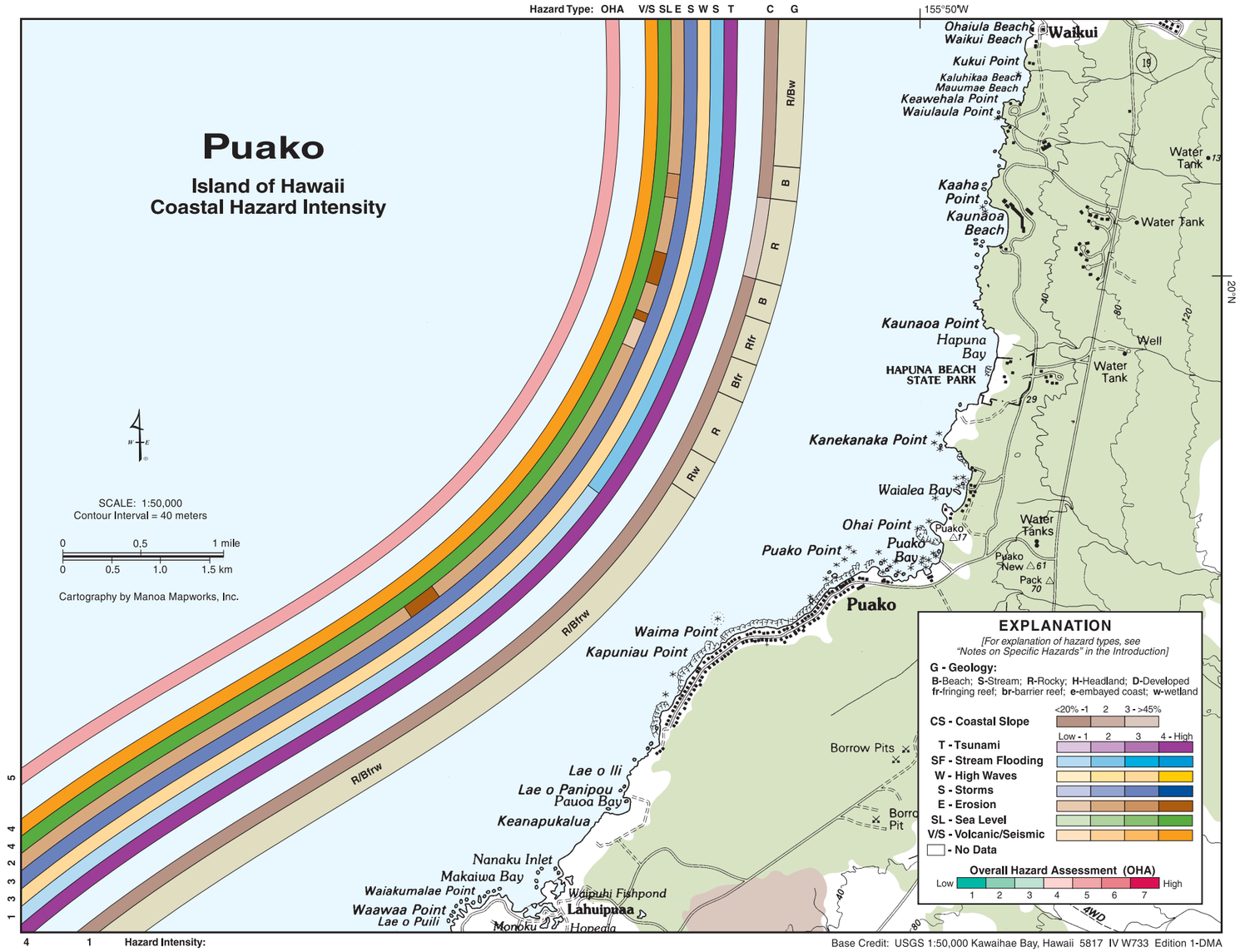
Between Hou Point and Waawaa Point, historic (1859 Mauna Loa flow) and prehistoric lava flows have created numerous coves and bays along the Anaehoomalu coast. Black and white sand beaches have formed in the low-lying Ohiki, Keawaiki, Pueo, Akahu Kaimu, Anaehoomalu, and Waiulua Bays. Most of these bays, however, have rocky bottoms or only thin veneers of sand offshore. Surrounding the bays are small but steep rocky headlands at Kaiwi and Lulahala Points. Anaehoomalu and Honokaope Bays are extensively developed with resorts and golf courses amidst wetlands and old fish ponds. Rock outcrops closely line the entire shore while an expansive fringing reef exists between Pueo and Waiulua Bays. Very little rain falls in this region and freshwater flow to the sea generally occurs within the porous rocks.

The Overall Hazard Assessment (OHA) for the Anaehoomalu coast is moderate to high (5), except between Lulahala and Waawaa Point where the rocky headland partly mitigates marine overwash and the OHA is moderate (4). Along the headland coast of Honokaope Bay, the tsunami and sea-level hazards are moderately low, while on either side they are high. Stream flooding is low along the entire coast due to the low rainfall and runoff. High waves and storms are both moderately high because this coast receives northwest and west swell as well as moderately high winds and waves from passing Kona and tropical storms. Erosion is moderately low, except at the Anaehoomalu beach immediately seaward of Kuuali Fishpond, where it is moderately high. Anaehoomalu lies in lava flow hazard zone 3 (Table 10, p. 24). The volcanic/seismic hazard is high due to recent lava flows in the area and active seismicity associated with Mauna Loa and Kilauea volcanos.

Despite a network of 1859 Mauna Loa lava flows that resemble rivers of rock and that reconfigured the shoreline, the Anaehoomalu coast has been extensively developed for tourism amidst arid lava fields.



Base Credit: USGS 1:50,000 Kawaihae Bay, Hawaii 5817 IV W733 Edition 1-DMA and Hualalai, Hawaii 5817 III W733 Edition 1-DMA



Alternating rocky points and beautiful coves containing white sand beaches adorn the gently sloping and embayed Puako coast.

Puako

The highly developed coast of Puako is lined with resorts and beach parks. The embayed Puako Bay is partly a result of the extension of the coast to the south by the more recent Mauna Loa lava flows. This is one of the most arid regions in Hawaii, receiving on average only ten inches of rainfall a year. Even so, precipitation on the flanks of Mauna Kea creates surface runoff that erodes the older rocks north of Waima Point, while to the south most freshwater flow is subsurface. Beaches of increasingly more white carbonate sand are found in the bays to the north. The widest white sand beach on the Big Island is located at Hapuna where lava flows border to the north and south. Wetlands have formed along the southern half of the coast and at Waiulaula Point. Fringing reefs are better developed south of Puako Point and between Kanekanaka Point and Hapuna Beach than at Puako Point and along the sandy beach expanses between Hapuna and Kaunaoa Bays.

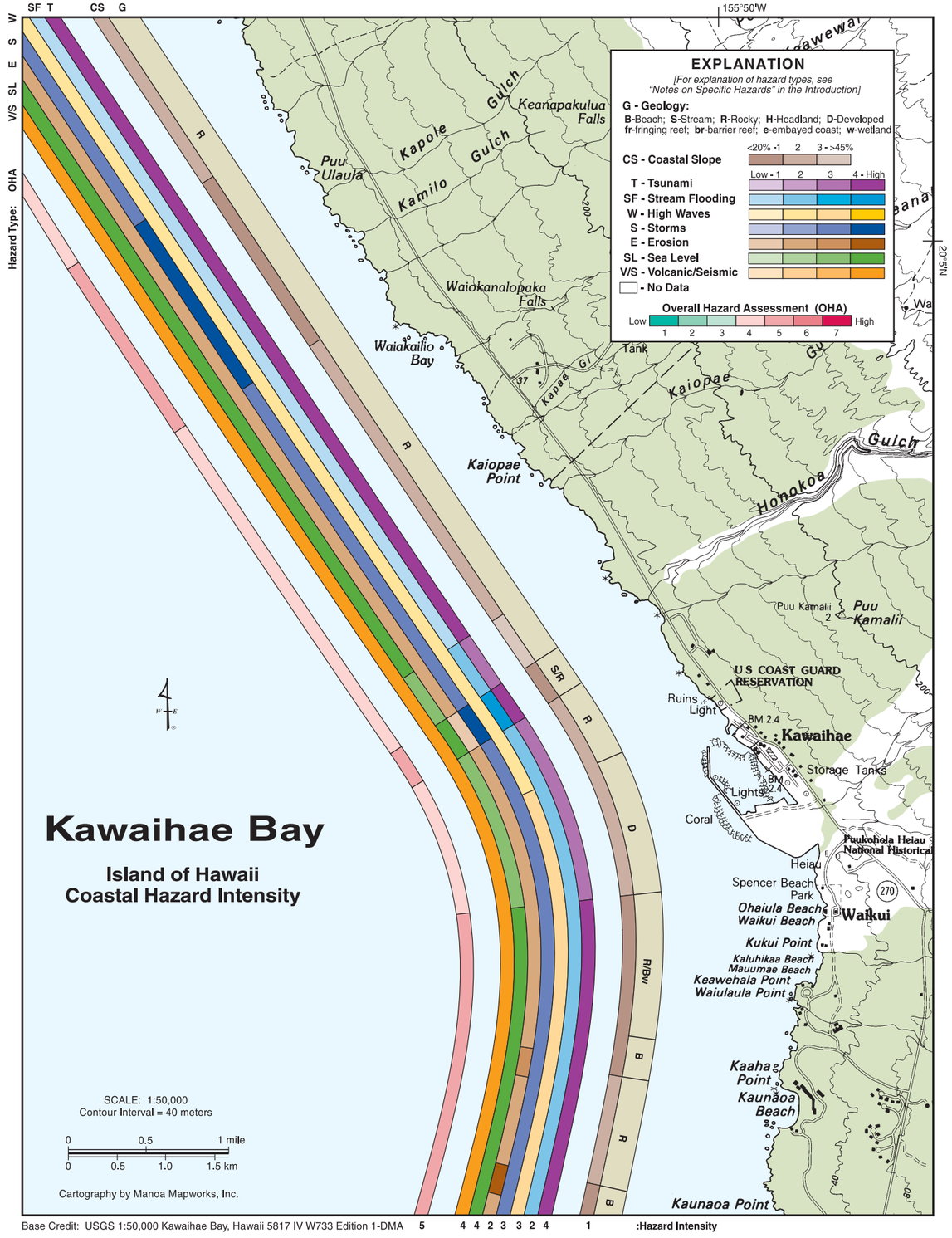
The Overall Hazard Assessment (OHA) for the Puako coast is moderate to high (5). The tsunami and sea-level hazards are high due to the low slopes which are susceptible to marine overwash. Stream flooding increases from low south of Waima Point to moderately low north of Waima Point, because of the increase in stream flow. High waves are moderately high because of Puako's exposure facing west and northwest swell directions. Storms are ranked moderately high because Kona storms and passing tropical cyclones deliver moderately high waves and winds to this portion of coast. Erosion is moderately low except at Pauoa and Hapuna Bays and the north portion of Waialea Bay where it is high. Exceptions also exist at the south end of Waialea Beach where erosion is low, and at Kaunaoa Beach where it is moderately high. South of Waima Point, amidst the younger Mauna Loa lava flows, the Puako coast lies in lava flow hazard zone 3. To the north, among the older Mauna Kea flows, it is in zone 8 (Table 10, p. 24). The volcanic/seismic hazard along the Puako coast is high due to the historical lava flows in the south near Lahuipuaa and the high seismicity associated with volcanic processes of Mauna Loa and Kilauea Volcanos.

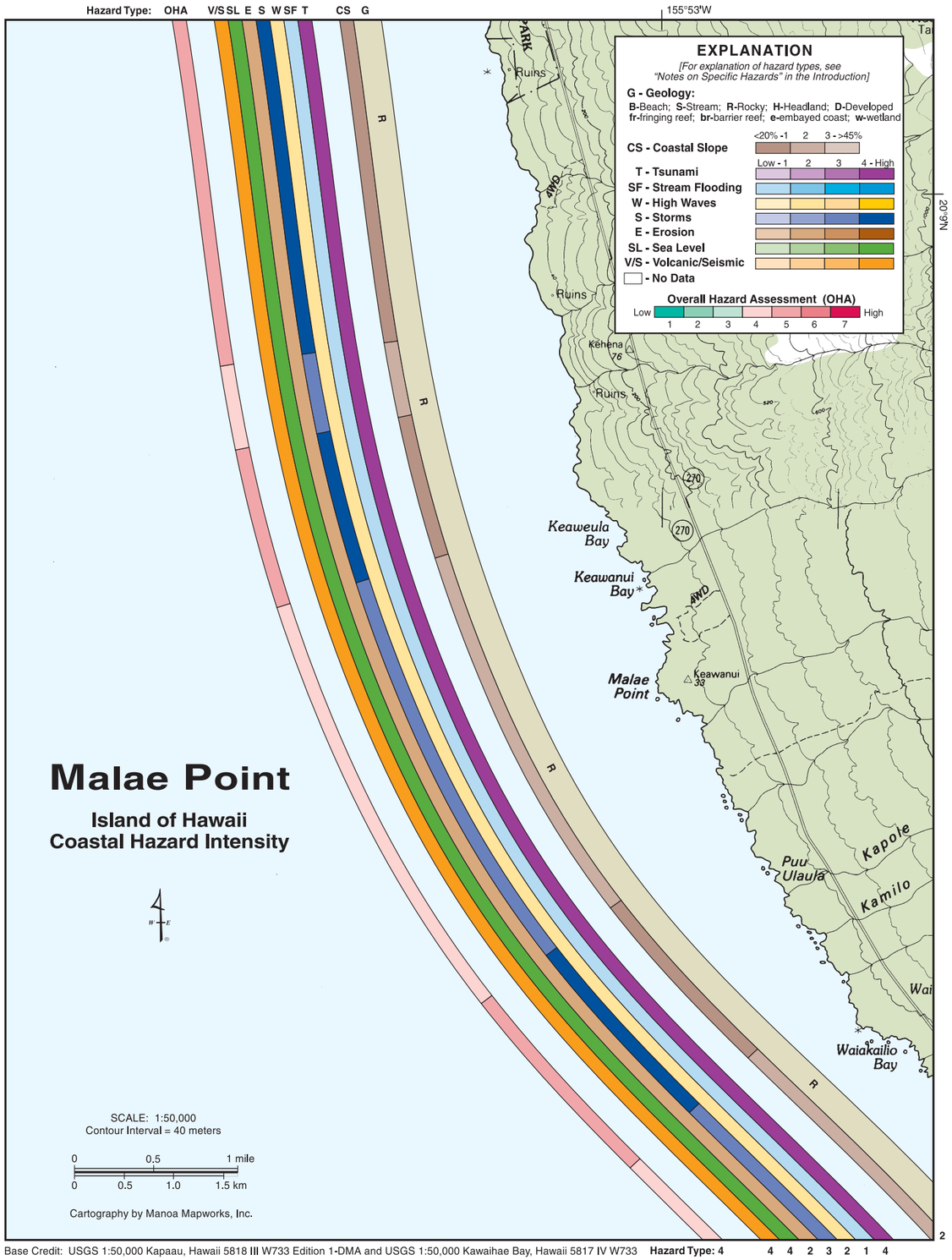
Kawaihae Bay

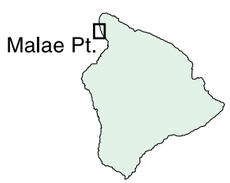
Along the Kawaihae Bay coast, Mauna Kea volcanics overlap older Kohala volcanics. The relatively low and gently sloping coast between Kaunaoa Beach and Waikui is rocky with interspersed sandy beaches including Kaunaoa, Mauumae, Kaluhikaa, Waikui, and Spencer Beaches. To the north the coast is largely rocky with steeper slopes and often 10-15 ft high sea cliffs. Waikui and Kawaihae are developed with industry and Kawaihae Harbor. An extensive coral reef exists around the harbor. Wetlands have formed south of Waikui while numerous rocky remnants lie offshore to the north. Several streams and gulches make their way to the sea along the older Kohala volcanic slopes. The Kawaihae region is very arid.

The tsunami and sea-level hazards are ranked high along the Kawaihae coast except along the steeper headland from Kawaihae Harbor to just south of Kaiopae Point, where they are moderately high. Stream flooding is low north of Kaiopae Point and moderately high to the south except at the mouth of Honokoa Gulch where it is high. The wave hazard is moderately high south of Kawaihae where the coast faces west towards northwest-approaching swell. To the north it is reduced to moderately low because the coast faces smaller waves that approach from the southwest. Storms are moderately high except at the low-lying and south-facing mouth of Honokoa Gulch and the rocky stretch of coast between Waiakailio Bay and Puu Ulaula. South of Waikui the coast lies within lava flow hazard zone 8, while to the north it is located in zone 9 (Table 10, p. 24). The volcanic/seismic hazard is high due to the high seismic activity associated with volcanic processes of Mauna Loa and Kilauea Volcanos. As a result, the Overall Hazard Assessment (OHA) is moderate to high (5) south of Waikui, at the mouth of Honokoa Gulch, and between Waiakailio Bay and Puu Ulaula, and only moderate (4) along the steeper coasts in between.

Developed for industry and commerce, the low-lying Kawaihae Harbor is located where the gently sloping coast of Waikui meets the steeper and sea-cliffed coast along the flanks of Kohala Volcano.







Malae Point

The Malae Point coast consists largely of low sea cliffs and several small rocky coves and bays separated by prominent headlands. Only a few cobble beaches exist along the entire stretch. Numerous rock islets and remnants lie offshore. The region is undeveloped except for old ruins surrounding the old coastal trail. Access is only by foot trail or four-wheel-drive vehicle. It is very arid although many intermittent streams and gulches cut across these moderate slopes, evidence that periodic flooding has occurred in the past. Trade winds blow generally offshore along this coast which creates good diving conditions. Only a few patch reefs have developed, however.

The Overall Hazard Assessment (OHA) is moderate (4) along the steeper headlands of Waiakailio Bay, between Puu Ulaula and Keaweula Bay, and to the north of Keaweula Bay. The OHA is moderate to high (5) in the immediate vicinity of Keaweula Bay, Waiakailio Bay, and Puu Ulaula and along the north portion of the Malae Point coast which are moderate to low lying. While the tsunami, sea level, and volcanic/seismic hazards are high throughout the entire coast, it is the variation in the storm hazard that influences the variation in the OHA ranking. Along the low sloping coastal segments the storm hazard is high, whereas along the moderate to steep slopes it is moderately high. Stream flooding is low, while high waves are moderately low throughout the entire Malae Point coast. Erosion is moderately low along these rocky, sea-cliffed shores. The Malae Point coast lies in lava flow hazard zone 9 (Table 10, p. 24).

Despite the rocky sea-cliff shoreline and vegetated upland slopes, recent development in the vicinity of Malae Point has led to an increase in sedimentation in the coastal zone during periodic heavy rains.

Mahukona

Between Lapakahi State Historical Park and Hianaula Point, the Mahukona coast is arid and generally rocky, with numerous small headlands. Near Lapakahi State Historical Park the coast gently slopes into the water, while to the north the coast is mostly bordered by sea cliffs. Cobble beaches exist just south of Kaoma Point and at Mahukona Beach Park. The harbor at Mahukona used to serve the Kohala sugar plantations, but the April 1946 tsunami destroyed its railroad link to the Hamakua coast. The harbor now provides a small winch and chain hoist for use by recreational boaters. Archaeological structures and ruins remain strewn across this coast, evidence that it used to be significantly populated.

The tsunami hazard is high except at Makaohule Point headland where it is moderately high. Stream flooding is low along the entire Mahukona Coast. The wave hazard is moderately low in the southern portion but is increased to high halfway between Haena and Hianaula Points and to the north, where north and northwest swell impact the coast. Storms are high along the lower slopes south of Kaoma Point, between Mahukona Harbor and Makaohule Point, at Kapaa Beach Park, and in the northern region. Along the steeper slopes north of Kapaa Beach Park for about two miles, between Kapaa and Makaohule Point, and at Mahukona Harbor, the storm threat is reduced to moderately high. Erosion is moderately low while the volcanic/seismic threat is high due to high seismicity associated with volcanic processes within Mauna Loa and Kilauea Volcanos. Mahukona lies within lava flow hazard zone 9 (Table 10, p. 24). Sea level is high except at the Makaohule Point headland where it is moderately high. As a result, the Overall Hazard Assessment (OHA) is moderate to high (5) south of Kaoma Point, between Mahukona Beach Park and Makaohule Point, and at Kapaa Beach Park due to the increased storm hazard. The OHA is reduced to moderate (4) at Mahukona Harbor and between Makaohule Point and Kapaa Beach Park. A moderate (4) OHA extends from Kapaa Beach Park to the midpoint between Haena Point and Hianaula Point, where it is elevated to high (6) because of the increased high wave and storm hazards that extend toward the north.

Once an important shipping port for the sugar industry, Mahukona Harbor suffered significant damage during the 1946 tsunami and is now used only for small boating.