APPENDIX C

WATER QUALITY, MARINE BIOLOGICAL AND NATURAL RESOURCES IMPACTS ASSESSMENT

Kahului Commercial Harbor 2025 Master Plan Environmental Assessment

Water Quality, Marine Biological and Natural Resources Impacts Assessment

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Introduction

Kahului Harbor is located on the south side of Kahului Bay on the north coast of the island of Maui (Figure 1). Waihee Reef extends 0.7-mile northwest of the breakwaters, and Spartan Reef extends 1.2 miles east of the breakwaters.

The commercial deep-water port of Kahului is on the southeast side of Kahului Harbor. The harbor is protected by two rubble mound breakwaters which extend outward from the east and west shores and enclose an area of about 200 acres. The entrance to the harbor is in deep water from the north through a 600-foot-wide opening between the outer ends of the breakwaters. The channel then turns sharply southeast to the Kahului Piers. The channel and basin are maintained at or near a 35-foot depth. The west part of the inner harbor is shallow. The southeastern shoreline consists of fine-grained sand beaches. The southwest shoreline is gravelly. The prevailing winds are the northeast trades, and harbor currents are weak.

Kahului has regular interisland barge service and is a port of call for transpacific vessels. Large vessels may anchor outside the breakwaters. Small craft have plenty of anchorage room in the unimproved areas behind the breakwaters. Vessels approaching the harbor entrance need to avoid the reefs. Product loading at Kahului Harbor occurs at Pier 3 located on the eastern side of the harbor within the commercial basin.

The State of Hawaii, Department of Transportation, Harbors Division (DOT-HAR) is proceeding with implementation of improvements at Kahului Harbor as outlined in the Kahului Commercial Harbor 2025 Master Plan, September 2000. An Environmental Assessment is being prepared under HRS 343 and possibly NEPA to assess the potential for significant impacts by the proposed harbor improvements. The proposed construction, particularly dredging and in-water construction, may have direct or indirect impacts on marine biological communities or natural resources.

In support of the EA, studies were conducted to address the potential for impacts to water quality, marine biological communities and natural marine resources in and adjacent Kahului Harbor as a result of the proposed improvements.

Water Quality Conditions

Methods

Water quality conditions within Kahului Harbor are influenced by a range of factors, including tidal exchange with nearshore waters outside the harbor, the pattern of flow and circulation within the harbor, surface discharge from surrounding lands during heavy rainfall events, and continuous discharge of nutrient-laden groundwater. The largest and longest term influences are expected to be related to season. In order to characterize in more detail the current water quality conditions in the harbor, water quality surveys were conducted on October 16, 2002, under light winds and scattered rain squalls, and on April 15, 2003, under strong trade winds.

Water quality parameters measured during the impact study include those listed in the State of Hawaii water quality criteria for marine waters. Additional parameters provide information on groundwater sources and potential public health problems, and have been measured in previous assessment and monitoring surveys. The instrumentation and methods used for each analysis are presented in Table 1.

On October 16, 2002, water samples were collected at eight shoreline stations (S1 – S8), one station located along the east arm of the harbor (E1), six stations within the harbor entrance channel and turning basin (H1 – H6), four stations in nearshore coastal waters immediately outside the harbor (NS 1 – NS4) and one station in the small stream which empties into the harbor along its western side (Stream). All station locations are shown in Figure 2. Samples could not be collected at a shallow nearshore station (NS5) and at stations along the western arm of the harbor (W1 – W2) because of high surf.

On April 15, 2003, water samples were collected at seven shoreline stations (S1 – S7), one station located along the east arm of the harbor (E1), three stations along the western arm of the harbor (W1 – W3), nine stations within the harbor entrance channel and turning basin (H1 – H9), and three stations in nearshore coastal waters immediately outside the harbor (NS2 – NS4). All station locations are shown in Figure 2. Samples could not be collected at a shallow nearshore stations (NS1, NS5) because of high surf.

For the shoreline stations on both surveys, a single sample was collected from just below the surface in water less than 0.5 m deep. For all other stations on October 16, three samples were collected: one just below the surface, one at mid-depth, and one 0.5 m above the bottom. On April 15, samples were collected just below the surface and 0.5 m above the bottom.

At each station on October 16, measurements of temperature and dissolved oxygen were made *in situ* with a portable temperature/DO sensor. For both surveys, water samples were collected with a Niskin bottle which was triggered to collect a sample at a specific depth. Upon retrieval, water samples were placed in 1 liter polyethylene bottles and held on ice for shipment to the analytical lab. On October 16, pH and turbidity were determined within 2 hours after collection. Upon receipt at the lab, subsamples of each sample were filtered for determination of total suspended solids and chlorophyll. The filtrate was analyzed for total dissolved nitrogen and phosphate, nitrate, nitrite, ammonium, reactive phosphate and silicate. Unfiltered subsamples were analyzed for salinity.

Table 1. Water quality parameters examined during the study, and analytical method.

Water Quality Parameter	Collection and Analysis Method
Dissolved Oxygen	Portable dissolved oxygen meter
Temperature	Portable dissolved oxygen meter
Salinity	Laboratory salinometer
pH	Portable pH meter
Water Samples:	5-liter Niskin bottles
Nutrients	Technicon AutoAnalyzer II;
Total nitrogen	D'Elia et al., 1977
NH_4	Solorzano, 1969
NO_3/NO_2	Technicon Inc., 1977
Total Phosphorus	Grasshoff et al., 1983
Orthophosphate	Murphy and Riley, 1962
Silicate	Strickland and Parsons, 1972
Chlorophyll	Filtration, acetone extraction, Turner Designs fluorometer; Strickland and Parsons, 1972
Turbidity	Turner Designs nephalometer; Standard Methods, 1992
Total Suspended Solids	Filtration, Cahn electrobalance Standard Methods, 1992

Results

Results of water quality analyses on samples collected at Kahului Harbor on October 16, 2002 are presented in Table 2. Samples were collected between 9:00 am and 12:20 pm, on a rising tide. Dissolved oxygen and temperature data were not collected at depths greater than 5 m, the length of the probe cable. The shallow bottom at station NS4 limited sampling depths to 2 m. Due to high surf breaking over the reef, samples were not collected at station NS5. Shallow bottom depths at stations H4 and H5 limited maximum sample depths to 8 and 5 m, respectively. An additional sample ("Stream") was collected in the small stream located at the eastern end of the harbor beach, approximately 50 m inland from the shoreline (Figure 2).

Water temperature was generally uniform between nearshore stations, and between surface and 5 m depths at nearshore stations. Within the harbor, surface waters tended to be 0.3 - 0.7 deg C cooler than 5 m depths, reflecting surface cooling associated with passing rain showers and light trade winds. Shoreline water temperatures were generally 0.3 - 0.5 deg C warmer than surface harbor waters, probably reflecting solar warming, as shoreline samples were collected in early afternoon.

Dissolved oxygen concentrations were generally typical of nearshore marine waters, ranging from 6.0 to 4.8 mg/l, values that are greater than 90% saturation at their respective temperatures and salinities. pH levels varied little and were typical of nearshore marine conditions.

Salinity levels were lower than typical for Hawaiian waters, ranging from 29.66 at the shoreline station S2 to 34.35 in nearshore samples outside the harbor. Depressed salinity levels reflected the recent input of freshwater by rain and runoff.

Turbidity levels were highly variable between nearshore stations, increasing from west to east, and reflecting visually-observed decreases in water clarity due to high surf and resuspended sediments on the western stations and both resuspended sediments and stream-borne sediments discharged during earlier heavy rains to the east. Nearshore turbidity levels ranged from 1.6 to 10.4 NTU. Turbidity levels within the harbor were not different from those in nearshore waters outside the harbor, and ranged from 1.9 to 9.4, with a very high value from a near-bottom sample (37.6 at E1). Turbidity levels at shoreline stations within the harbor (S2 - S7) reflected variable shoreline wave action and build-up of detached macroalgal material. Shoreline station S8 was taken to the east of the sewage treatment plant, in an area of high turbidity (234 NTU) consisting of red soil particles discharged from adjacent streams during recent heavy rainfall. Overall, Turbidity levels were highly significantly related to Total Suspended Solids ($Turb = -147 + 4.95 * TSS$; $r^2 = 0.81$, $p < 0.01$), and showed the same patterns of distribution and concentrations.

Levels of dissolved nutrients reflected the strong influence of groundwater influx to the harbor. Plots of silicate vs. salinity, nitrate + nitrite vs. silicate and phosphate vs. silicate are presented in Figure 3a – c, respectively. Increasing levels of silicate with decreasing salinity reflect the dilution of low silicate nearshore coastal seawater with high silicate groundwater. The majority of the data fall along a single line; however a group of five samples with a lower silicate-salinity line comprise samples collected at S1 and NS 2 – 3, stations outside and to the north of the harbor. These data suggest a groundwater source with a somewhat decreased silicate load.

The nitrate + nitrite vs. silicate (Figure 3b) and phosphate vs. silicate (Figure 3c) plots show the strong relation between silicate and other dissolved nutrients, suggesting a common upland source. Only samples from shoreline station S2 and S3, located along the western shoreline of the harbor, showed a different nitrogen : silicate and phosphorus : silicate ratio, suggesting a local source of additional nutrients.

Chlorophyll levels were generally low and showed no systematic relationship to salinity (Figure 3d). Elevated chlorophyll levels were observed at shoreline stations (S2 – S4) along the western coastline of the harbor.

A second water quality survey was conducted in Kahului Harbor on April 15, 2003, during a period of strong trade winds. Results of this second survey are presented in Table 3. Samples were collected between 9:00 am and 12:20 pm, on a rising tide. Dissolved oxygen and temperature data were not collected during this survey, as the prior survey showed little horizontal or vertical variation in these parameters. The shallow bottom at station NS4 limited sampling to the surface sample only. Due to high surf breaking over the reef, samples were not collected at stations NS1 and NS5.

Water quality conditions at the nearshore stations outside the harbor were typically open coastal in nature, with higher salinity levels (34.14 – 34.89 ppt) than observed during the previous survey under light Kona conditions. Levels of dissolved nutrients were consequently low, and typical of open coastal waters with little groundwater influence.

Waters within the harbor were highly stratified, despite the strong wind conditions. Salinity at stations along the western portion of the harbor (H3, H5, H6, H7, H8 and H9) showed salinity levels of 35 ppt in near-bottom samples, and salinity levels of 29.77 – 33.82 ppt in surface samples. Reflecting the strong groundwater input, dissolved nutrient levels were also elevated in surface samples, with NO2+NO3 levels ranging from 10.2 – 30.6 uM, and NH4 levels ranging from 0.58 – 2.44 uM.

Samples collected along the shoreline again showed strong influence of groundwater, with salinity of samples collected within the western part of the harbor (S2 – S6) ranging from 27.2 – 32.59 ppt. Lowest salinities were observed at stations S3 and S4, located in the southwest corner of the harbor. Salinity at station S1, a shoreline station on the northern face of the western breakwater, outside the harbor, was similar to open coastal waters (34.39 ppt), as was salinity at S7, near the base of Pier 1 (34.67 ppt).

Levels of dissolved nutrients again reflected the strong influence of groundwater influx to the harbor. Plots of silicate vs. salinity, nitrate + nitrite vs. silicate and phosphate vs. silicate are presented for the April 15 survey data in Figure 4a – c, respectively. Increasing levels of silicate with decreasing salinity reflect the dilution of low silicate nearshore coastal seawater with high silicate groundwater. The majority of the data fall along a single line, suggesting a single groundwater source.

The nitrate + nitrite vs. silicate (Figure 4b) and phosphate vs. silicate (Figure 4c) plots show the strong relation between silicate and other dissolved nutrients, suggesting a common terrestrial source. Samples from shoreline stations S2 and S3, located along the western shoreline of the harbor, showed different nitrogen:silicate and phosphorus:silicate ratios, suggesting a local source of additional nutrients, or localized nutrient uptake.

Chlorophyll levels were generally low and showed no systematic relationship to salinity (Figure 3d).

Marine Biological Conditions

Nearby marine benthic and fish communities may be impacted by the transport and deposition of sediment suspended during construction and harbor dredging, or by changes in water quality. To assess the magnitude of these potential impacts, the nearshore biological communities have been characterized through compilation of historical data from the Kahului Harbor and immediate vicinity. The Maui Coastal Resource Inventory (AECOS, 1981) was the primary source of the following descriptive marine biological characterization.

Kahului Bay and Kahului Harbor

The general bathymetry of Kahului Bay, Kahului Harbor and adjacent coastal waters is shown in Figure 5. Kahului Bay is a broad embayment between the slopes of two volcanoes: Haleakala and West Maui. A sand channel entering Kahului Bay is believed to be a relic feature representing the ancient drainage course of Waikapu Stream.

Kahului Harbor, a fan-shaped basin at the head of Kahului Bay, is bounded on the east and northwest by long boulder and dolose breakwaters. The sand shoreline at the head of Kahului Harbor between Pier 2 and the shore along Kahului Beach Road is known as Kahului Beach. The beach is composed of brown, detrital sand and is broken by several boulder jetties built to retard erosion. Much of the southwest shoreline between the extreme south corner of the harbor and the coral fill area is a beach of gravel to boulder size rubble.

Much of the southern and southwestern perimeter of the harbor is fringed by a shallow reef shelf extending a few hundred feet offshore. Beyond the reef edge, the harbor bottom is a terrace of silty-sand and limestone rubble dipping gradually seaward to depths of over 50 feet (15 m). Off the sand beach west of Pier 2 is a sand bottom extending to a depth of 10 feet (3 m). Here, consolidated rock pocketed by sand is encountered. The seaward edge of this formation drops to the dredged basin forming the eastern portions of the harbor.

Sand bottom occurs at depths greater than 30 feet (9 m) outside the mouth of Kahului Harbor. The west breakwater overlies an irregular reef whose margin is about 15 feet (5 m) deep. Here, the limestone platform drops a short distance to a sand bottom continuing offshore from a depth of about 20 feet.

The crab, *Macrophthalmus telescopicus*, is the most conspicuous inhabitant of the silty-sand bottom nearshore between Piers 1 and 2 in the eastern harbor. Less common are solitary tunicates and a few small solitary heads of the coral, *Montipora* sp., in poor condition. *Mugil cephalus, Selar crumenophthalmus, Decapterus macarellus, Acanthurus triostegus, Etrumeus micropus, Kuhlia sandvicensis, Caranx ignobilis*, and *Chanos chanos* are reportedly common within the harbor.

East of Kahului Harbor

A shallow reef extends west from Pa'ia toward Kahului Harbor. The reef margin lies generally one-quarter mile offshore. A narrow band of sand borders the beach off much of the shore, but most of the reef platform is consolidated reef rock. The reef slopes to a depth of about 15 feet (5 m) over 1,000 feet (300 m) offshore from Ka'a. The limestone platform displays complex relief in the form of numerous arches, overhangs, and projections above the bottom. Surge channels and sand pockets occur over the surface of reef rock. Coral cover is sparse over the reef flat, but approaches 60% along the reef edge over 1,000 feet off Ka'a. *Porites lobata* is most abundant, although nearly equaled in abundance by *Montipora flabellata*. Algae are sparse, covering less than 5% of the bottom. *Laurencia* sp. is the most common species. The soft coral, *Palythoa tuberculosa*, is conspicuous. *Scarus* sp., *Acanthurus leucopareius*, *A. triostegus*, *Kyphosus* sp., and juvenile carangids dominate the fish assemblage.

Off the MECO plant the reef has a smooth surface 5 to 10 feet deep extending offshore a distance of about half a mile (800 m), beyond which the bottom drops abruptly. The reef surface is irregular off Hobron Point where depths of 30 to 35 feet (9 to 11 m) are reached within 1,000 feet from shore. The reef face is a steep drop-off to a deep sand bottom off of the east breakwater of Kahului Harbor. Hard corals are scarce and scattered along this high energy shallow reef. The red alga, *Acanthophora spicifera*, is the most common fleshy alga on the reef. Encrusting coralline algae are also abundant. The green algae, *Enteromorpha* and *Cladophoropsis*, increase in abundance near the thermal discharge of the MECO power station. Polychaetes, alpheid shrimp, xanthid crabs, and brittlestars are abundant in substratum samples taken from the reef fronting the power generating station.

Northwest of Kahului Harbor

The shoreline extending north from the west breakwater to Nehe Point is a continuous, narrow beach of rubble and boulders. A reef extends along the coast northwest of Kahului Harbor. The outer part of the limestone shelf off Paukukalo Beach is irregular with high vertical relief. Projections of reef rock rise above sand pockets from a depth of 15 feet (3 m). Small overhangs of reef rock occur along the sides of sand-bottom surge channels. Coral cover reaches 35% on the deeper slopes of the irregular reef flanking the west breakwater. *Montipora patula* is dominant. Algae are generally sparse, but total cover approaches 15% in places. *Halymenia formosa* and *Amansia glomerata* are most common. *Thalassoma duperreyi, Stegastes fasciolatus, Bodianus bilunulatus,* and *Plectroglyphidodon imparipennis* dominate the fish assemblage. Green sea turtles, *Chelonia mydas*, may be seen outside the western breakwater. The mussel, *Brachidontes crebristriatus*, is abundant in shallow waters off the east breakwater.

A submerged fringing reef fronts the coast between Kahului and Waihee Point. Southeast of Waiehu Point, the reef narrows to about 500 feet, half the width of the Waihe'e reef section. Volcanic rubble covers the back reef at the base of the beach. Just offshore the consolidated reef platform is covered by limestone rubble, interspersed with sand pockets. In some areas, reef rock rises above the rubble and provides vertical relief. The reef platform slopes gradually to a depth of about 6 feet (2 m) some 500 feet from shore. Near the reef edge, limestone rubble diminishes and sand deposits are predominant. Beyond the reef margin is a steep-sloping reef front. A sand channel (Kawili Channel) crosses the reef and approaches shore near the mouth of Waiehu Stream. Coral cover approaches 40% on the outer part of the reef bordering Paukukalo Beach. *Montipora patula* is most common. The sea urchin, *Echinothrix* sp., is abundant. Fleshy algae cover up to 10% of the bottom, with *Martensia* sp. predominating. *Rhinecanthus rectangulus, Chaetodon fremblii, Thalassoma purpureum, Acanthurus dussumieri,* and *A. triostegus* are the most conspicuous fishes.

The outer part of the reef off Ka'ehu Beach is a consolidated limestone shelf furrowed by numerous surge channels and sand pockets. Vertical relief is high. Limestone ridges project some 12 feet (4 m) above sand pockets at -20 feet (-6 m). Coral cover averages 20% on the outer part of the reef fronting Ka'ehu Beach. *Montipora patula* is most abundant. The soft coral, *Palythoa tuberculosa*, is common. Algal cover approaches 10%. *Martensia* sp. is most abundant. Few fishes are present: *Acanthurus triostegus* and *Thalassoma ballieui* are most conspicuous.

Off Waiehu Beach Park, the reef platform is interrupted by numerous surge channels, but vertical relief is less than in areas to the southeast. Sparse coral growth and few fishes characterize the reef platform fronting Waiehu Beach Park. However, this area is rich in algae, which covers about 75% of the bottom near shore, thinning out to 30% cover with increasing depth. *Ulva fasciata* and *U. reticulata* are the most abundant of at least 16 species (and one angiosperm), including several edible varieties. Only a few species of fishes are recorded in shallow waters between shore and the reef edge. Corals are abundant on the outer reef where at least 12 species are represented. *Porites lobata* dominates the cover, which totals 80%. The solitary coral, *Fungia scutaria*, is common, as well as *Montipora patula*. *Acanthurus dussumieri* is the most abundant fish.

Impact Analysis

The potential for significant impacts to regional water quality and adjacent marine communities due to the proposed Kahului Harbor improvements is small. Water quality conditions within the harbor and in adjacent open coastal waters are influenced primarily by the input of nutrient-rich groundwater and the resuspension of sediment by wave action. Groundwater input occurs all along the coastline, but appears to be higher than usual in the southwest corner of the harbor. Lowered salinity values and high levels of dissolved nutrients in this area demonstrate the localized source. Water quality conditions within the harbor and nearby coastal waters reflect the simple physical mixing of the high nutrient groundwater with low nutrient coastal water. None of the proposed harbor improvements will alter the quality of groundwater entering coastal waters, or change the location of groundwater discharge.

Physical oceanographic studies (EKNA, 2003) examined current patterns and water exchange rates in Kahului Harbor under several wind and tide conditions. Current studies using surface and subsurface drogues showed a generally closed circulation within the harbor, with little exchange with waters outside the harbor over a tidal cycle. Under strong trade wind conditions, surface flow was across the harbor to the west and over the shallow reef along the western side of the harbor. These circulation patterns tend to minimize the impact of sediment generated by construction activities on communities outside the harbor.

While some sediment and turbidity may be generated by the proposed construction activities, its impact on water quality and marine communities will be small. Levels of suspended particulates in the waters of the harbor and adjacent coastal waters are primarily the result of resuspension of bottom sediment by strong winds and/or wave action. The harbor basin is characterized by a bottom comprised of sand and mud. Under strong trade winds, vertical mixing may bring fine sediment suspended near the bottom up into surface waters. Ship traffic, especially large ships with drafts approaching the harbor bottom depth, can resuspend large amounts of sediment as they maneuver within the harbor. Typical surf outside the harbor also keeps fine sediment particles suspended in a layer 1 – 2 m in thickness above the bottom (pers. obs.). Within this system of naturally-occurring high turbidity and suspended solids loads, the addition of small, localized sediment sources will have little incremental impact.

The location and distribution of general bottom types within and in the vicinity of the mouth of Kahului Harbor can be seen in aerial photographs of the area taken May 24, 2000 (Plate 1). The edges of bottom features have been enhanced for clarity in the color plate. The extensive sandy-mud bottom of the harbor extends for a long distance to the north outside the harbor mouth.

Bottom depths range from approximately 30 feet at the harbor mouth to 60 feet at a distance of 1 km from the harbor mouth. Fringing reefs for several km on either side of the harbor (Figure 5) comprise scoured reef platforms with sparse coral and fish communities.

The area outside the harbor mouth potentially impacted by sediment from the harbor is small. Sea Engineering, Inc. (SEI, 2000) conducted a modeling study of sediment transport associated with the proposed dredging of additional berthing space in Kalaeloa Barbers Point Harbor, Oahu. Kalaeloa Barbers Point Harbor is similar to Kahului Harbor in having a harbor basin connected to coastal waters by a narrow entrance channel. The SEI study concluded that turbidity levels would rarely exceed ambient levels by 1 NTU at distances of 1 km from the harbor entrance. Since no dredging is proposed for the Kahului Harbor improvement project, these modeling results for Kalaeloa Barbers Point Harbor represent a worst-case scenario for Kahului Harbor. Construction-related turbidity is likely to remain within the harbor, or to be discharged through the harbor mouth into coastal waters where mixing and transport would rapidly disperse any turbidity plume, probably within less than 1 km from the harbor mouth.

REFERENCES

AECOS, Inc. 1981. Maui Coastal Resource Inventory. Prepared for U.A. Army Corps of Engineers, Pacific Ocean Division, Fort Shafter. 552 pp.

American Public Health Association. 1992. Standard Methods for the Examination of Water and Wastewater. Washington, D. C. 1193 pp.

D'Elia, C. F., P. A. Steudler and N. Corwin. 1977. Determination of total nitrogen in aqueous samples using persulfate digestion. Limnol. Oceanogr. 22: 760-764.

Grasshoff, K., M. Ehrhardt and K. Kremling, eds. 1983. Methods of Seawater Analysis. Verlag Chemie, Weinheim. 419 pp.

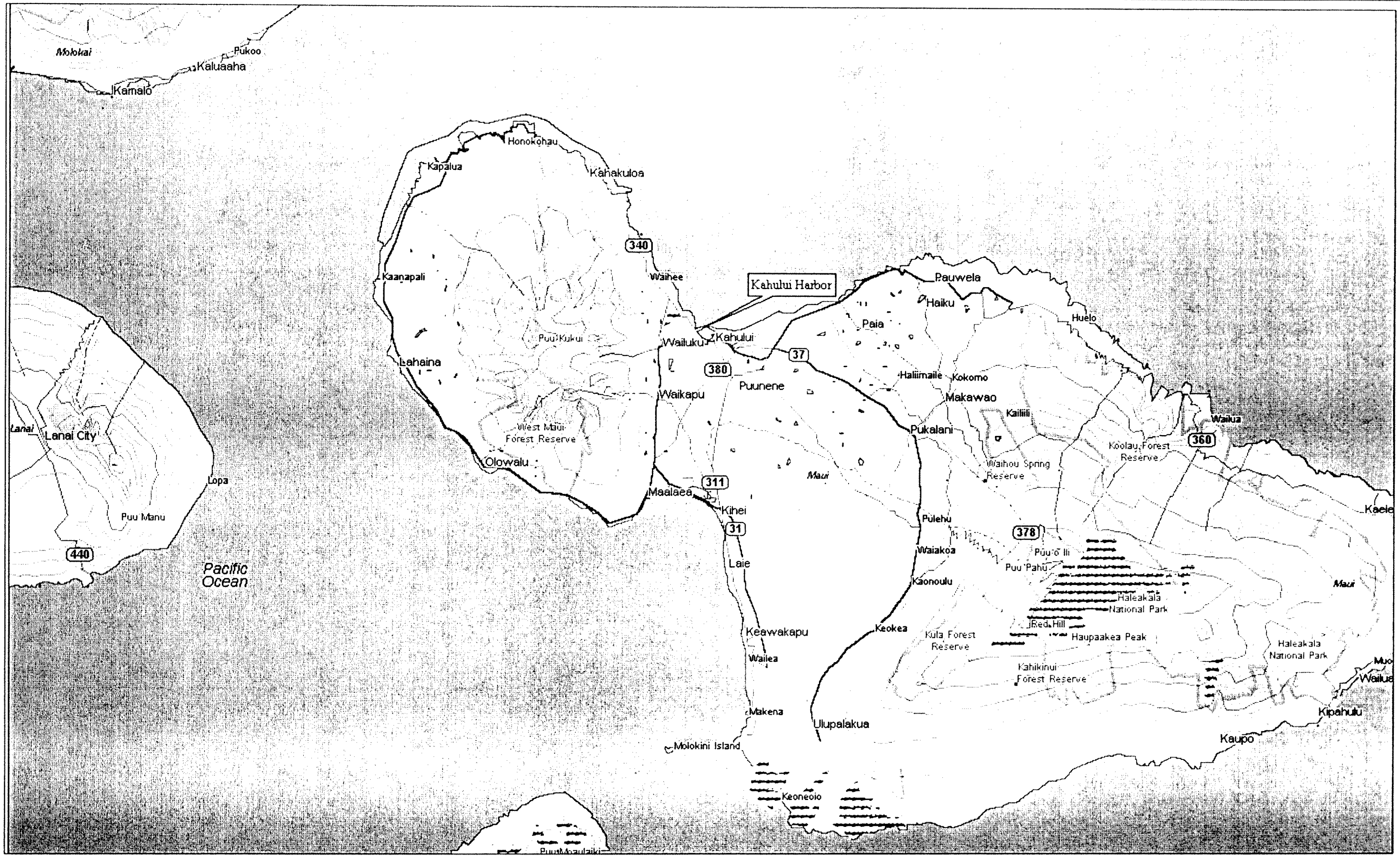
Murphy, J. and J. P. Riley. 1962. A modified simple solution method for the determination of phosphate in natural waters. Anal. chim. Acta 27: 31-36.

Sea Engineering, Inc. 2000. Modifications for Barbers Point Harbor: Evaluation of Turbidity and Jetty Construction. Prepared for Parsons Brinckerhoff, Honolulu. Individually-numbered sections.

Solorzano, L. 1969. Determination of ammonia in natural waters by the phenolhypochlorite method. Limnol. Oceanogr. 14: 799-801.

Strickland, J. D. F and T. R. Parsons. 1972. A Practical Handbook of Seawater Analysis. Bull. Fish. Res. Bd. Canada 167. 311 pp.

Technicon Inc. 1977. Nitrate and nitrite in water and seawater. Technicon, Inc. Industrial Method No. 158, f/w/a.



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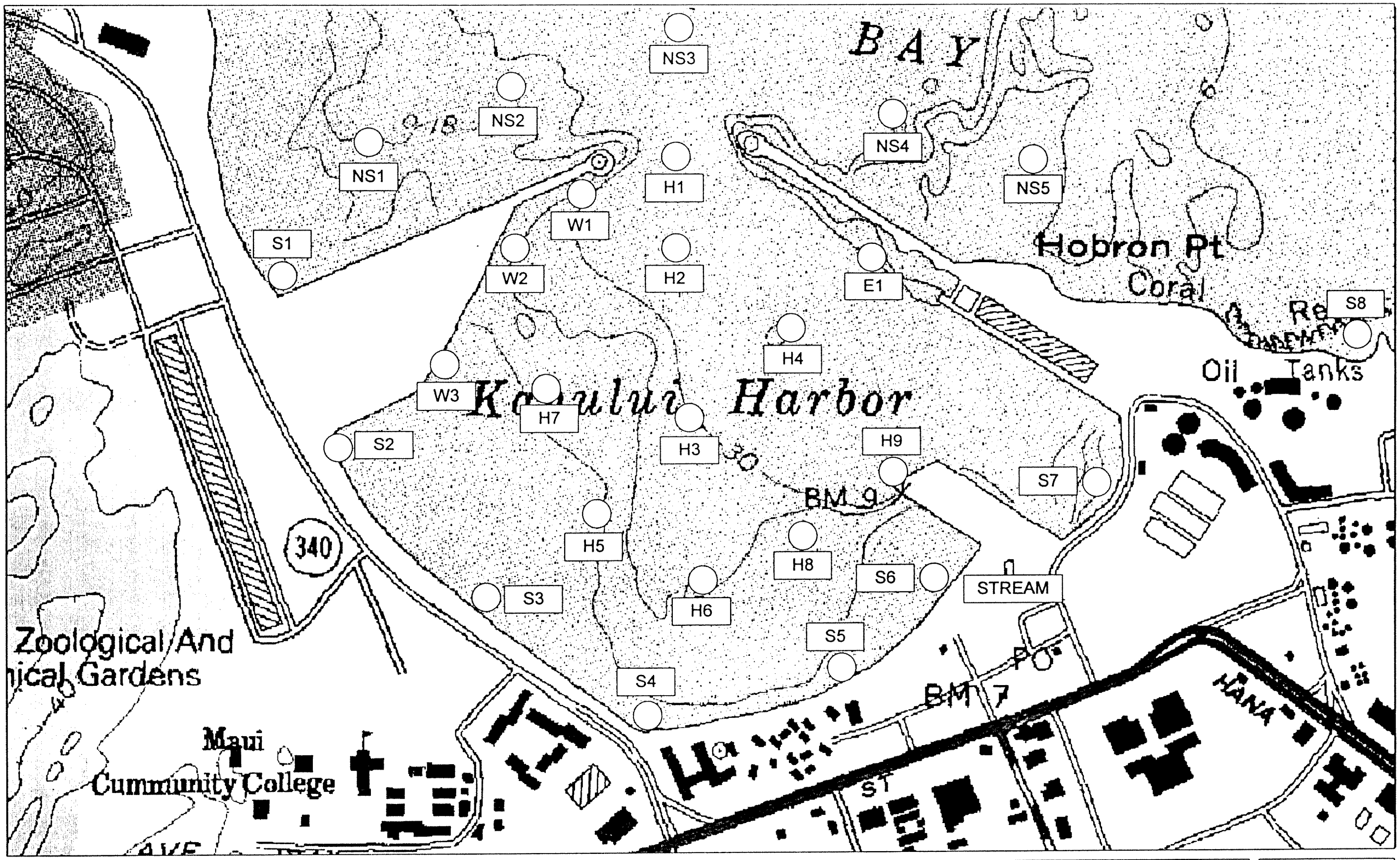
Kahului Harbor Location

Figure 1



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Kahului Commercial Harbor 2025 Master Plan Environmental Assessment

Location of Water Quality Survey Stations ○

Figure 2

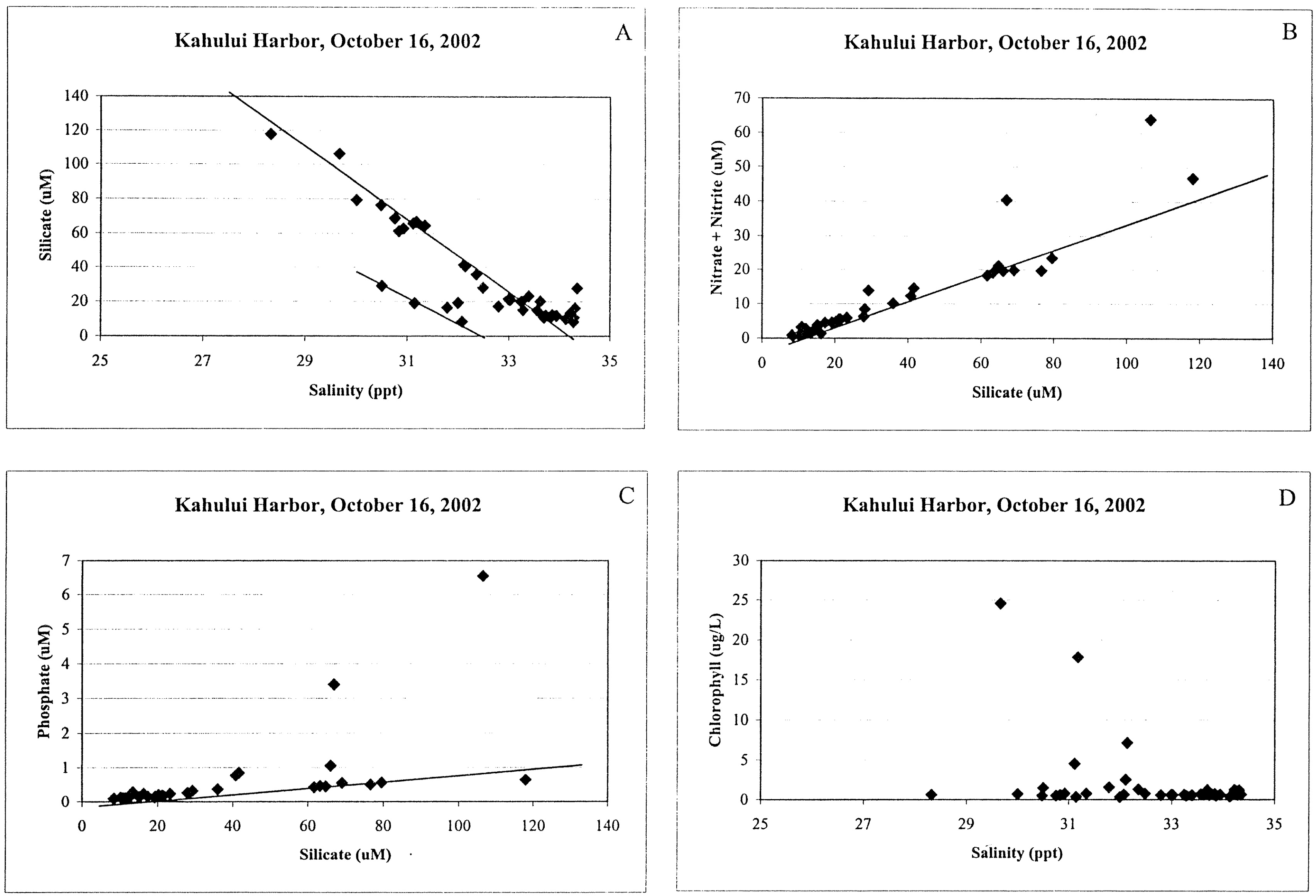


Figure 3. Plots of water quality data for survey conducted at Kahului Harbor, Hawaii, on October 16, 2002.

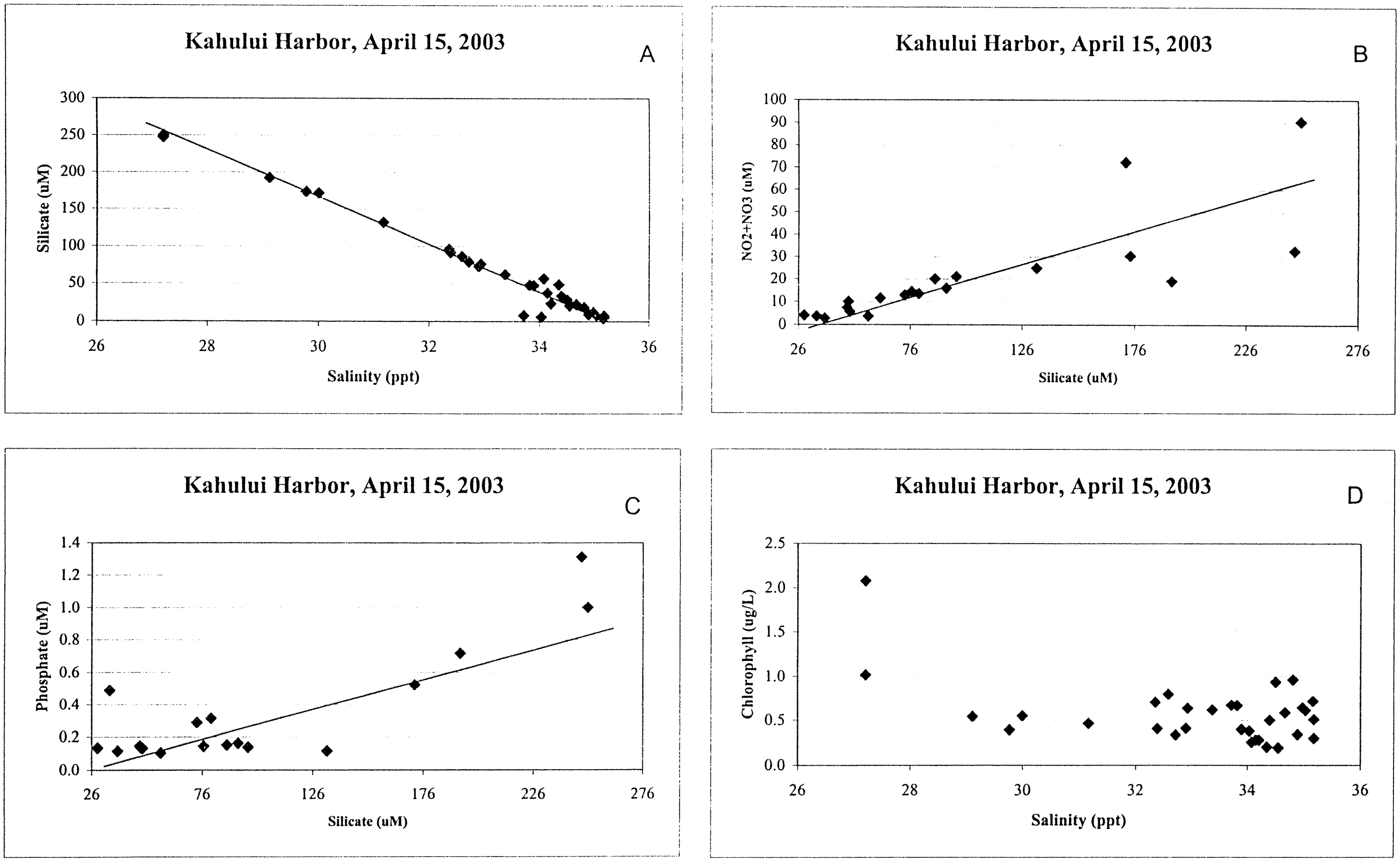
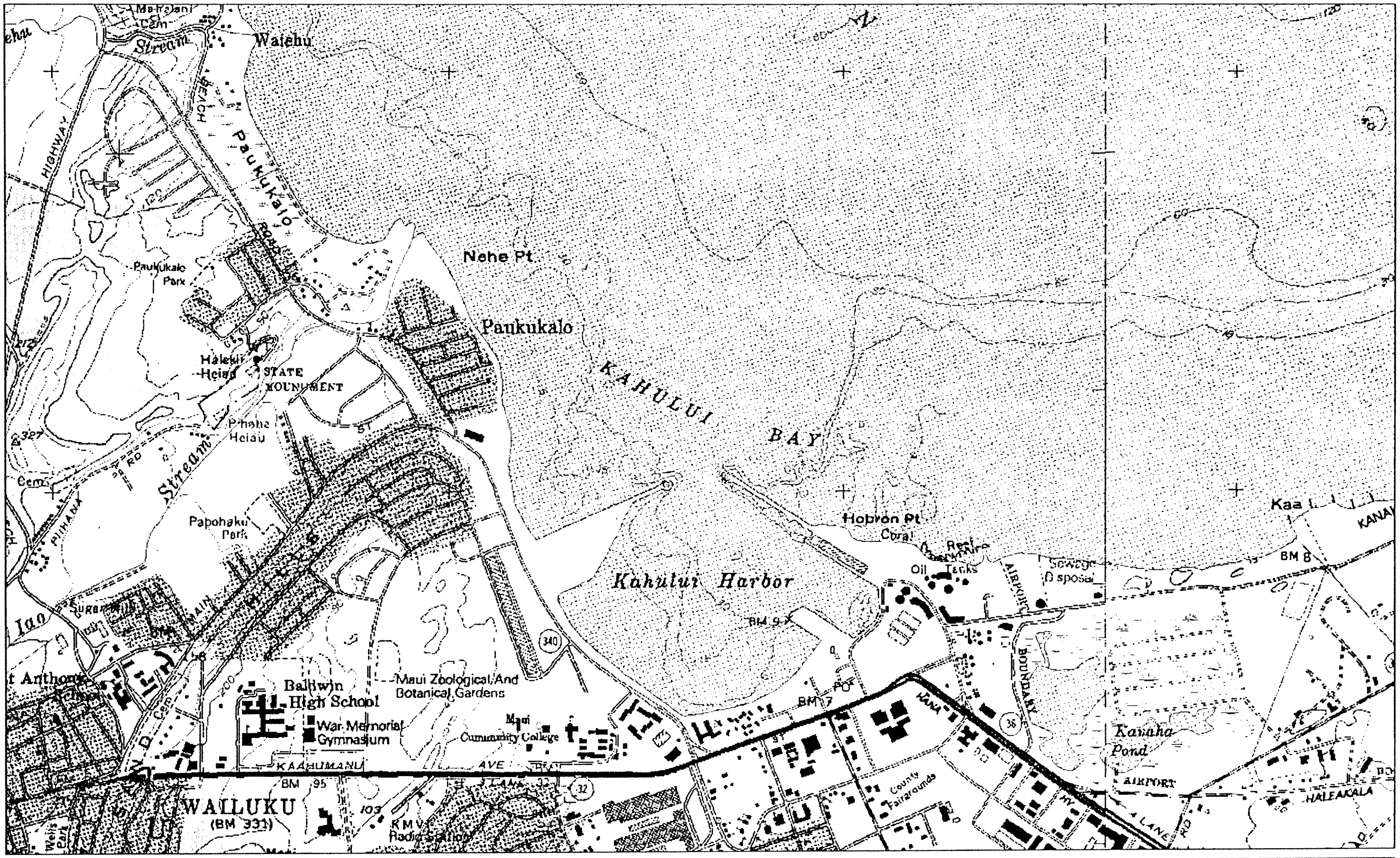


Figure 4. Plots of water quality data for survey conducted at Kahului Harbor, Hawaii on April 15, 2003.



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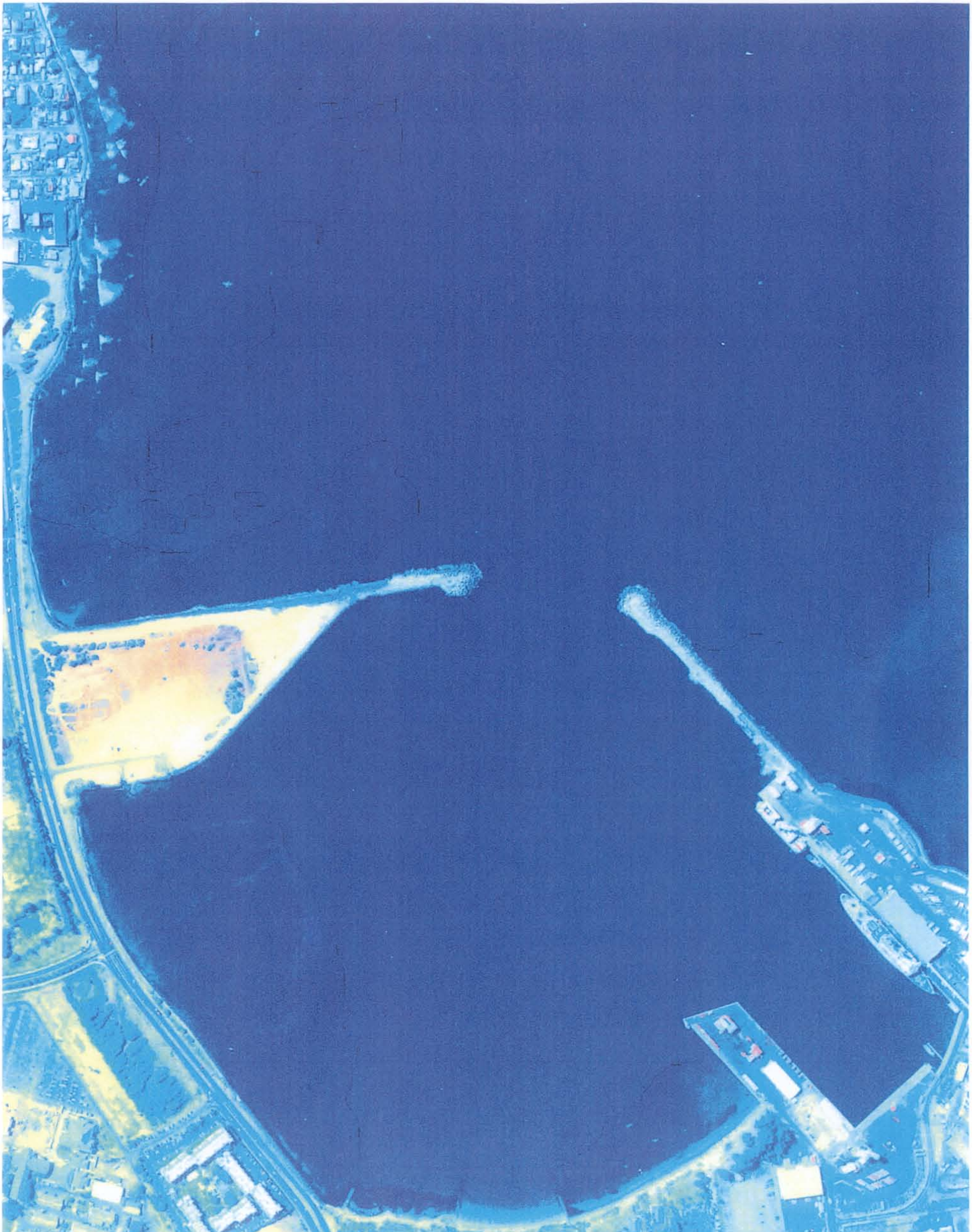
Kahului Harbor Offshore Bathymetry

Figure 5



APPENDIX D

KAHULUI HARBOR CURRENT DROGUE MEASUREMENTS AND CTD PROFILES

KAHULUI HARBOR CURRENT DROGUE MEASUREMENTS
AND CTD PROFILES
KAHULUI, MAUI, HAWAII

Prepared For:

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
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KAHULUI HARBOR CURRENT DROGUE MEASUREMENTS AND CTD PROFILES KAHULUI, MAUI, HAWAII

Kahului Field Measurement Results.

October 15 Drogue Measurements (See Figure)

Drogue measurements on this day were taken during the ebb stage of the tide. The weather was sunny to partly sunny and the wind was light and variable tending weakly from the south toward the end of the measurement period. Six drogues were deployed from west to east across the middle of the harbor. Three were set to measure currents at 25 foot depth and three were set for shallow currents at five foot depth. The deep drogues traveled generally from the south to north during the measurement period at average speeds of 2.5 to 3.6 cm/sec, whereas the shallow drogues traveled north to south at average speeds of 3.6 to 4.1 cm/sec, with the exception of the drogue deployed in the basin between Piers 1 and 2. This drogue traveled from the southwest to the northeast throughout the measurement period at an average speed of 3.4 cm/sec.

October 17 Drogue Measurements (See Figure)

Drogue measurements on this day were taken during the flood stage of the tide. The weather was generally cloudy and rainy with light to no wind. A total of ten drogues were deployed near the mouth of the harbor. Six physical drogues were used for these ten deployments. If a drogue exited the harbor it was picked up and redeployed within the harbor mouth. Also during this measurement period the drogues had to be picked up and redeployed due to barge traffic into and out of the harbor. Three drogues were set to measure at the 25 foot water depth and three drogues at the 5 foot water depth. Of the ten deployments four were at the 25 foot depth and six at the 5 foot depth. The deep drogues tended to travel into the harbor from the mouth moving generally from the north to the south at average speeds of 2.9 to 3.4 cm/sec. All of the shallow drogues deployed near the mouth tended to travel out of the harbor moving from south to north at average speeds of 3.5 to 6.2 cm/sec.

April 15 Drogue Measurements (See Figure)

Drogue measurements on this day were taken during the flood stage through high tide and into the ebb stage. The weather was mostly sunny with steady 20 knot trade winds. A total of nine drogues were deployed throughout the day. Three drogues were set to measure at the 25 foot depth and six were set to measure at the 5 foot depth. They were deployed across the harbor in a line approximately midway between the harbor mouth and the middle of the harbor. In all cases the drogues tended to travel from the northeast to the southwest showing the direct influence of the trade winds on the circulation pattern in the harbor. The average speeds of the deep drogues ranged from 2.9 to 6.3 cm/sec and for the shallow drogues from 6.5 to 14.7 cm/sec. None of the flow variability of the October drogue measurements was evident in this data set.

April 15 CTD Measurements (See Figures)

The temperature profiles during the flood stage show near the mouth of the harbor (NS3 and

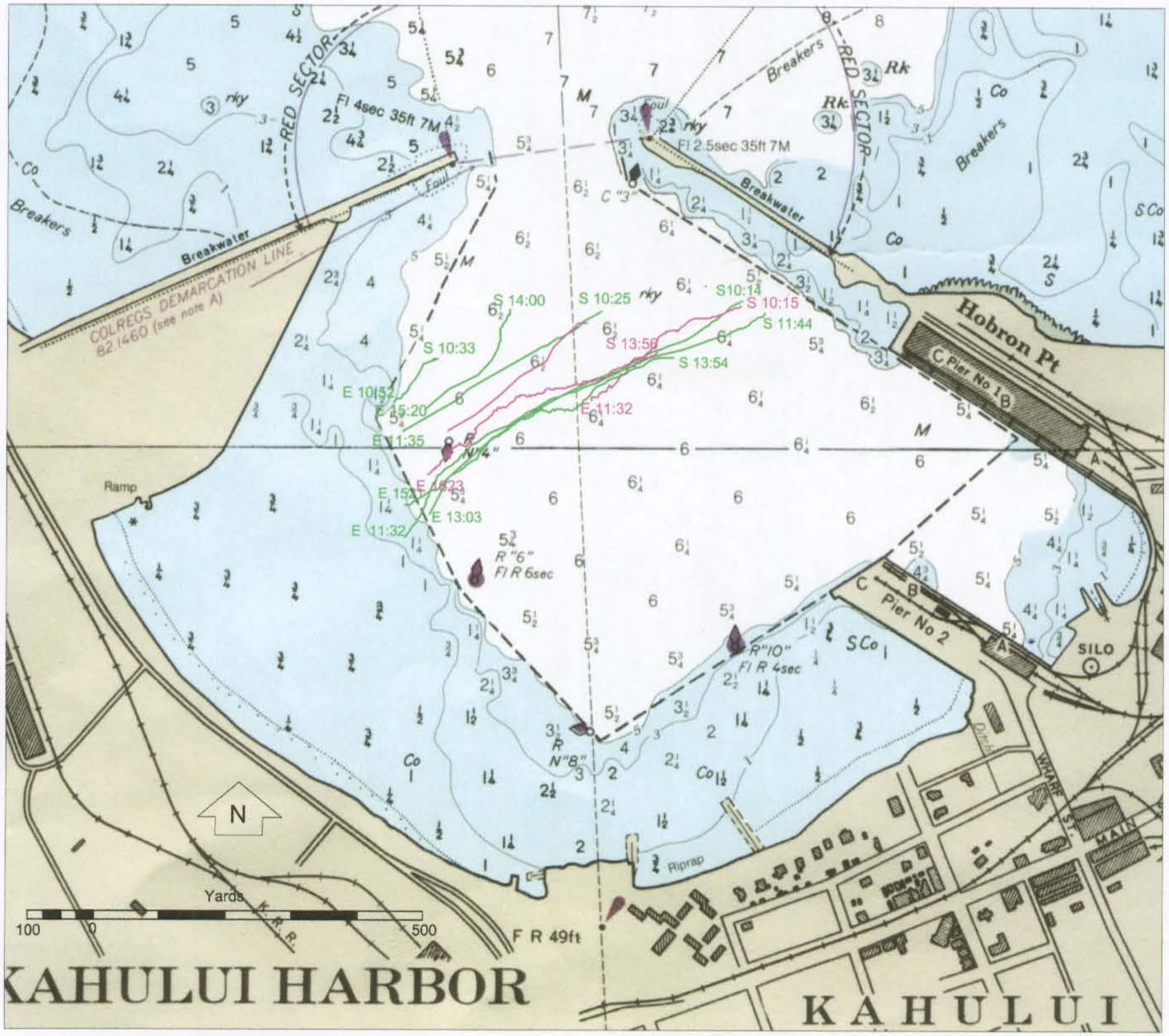
H1) a 1 degree warmer layer of water from 20 to 30 feet deep between cooler upper and lower layers of water. The cooler surface layer is persistent throughout nearly all stations measured. During the ebb stage in the late afternoon the measurements show the surface layer to be warmer than the deeper layers by 1 degree.

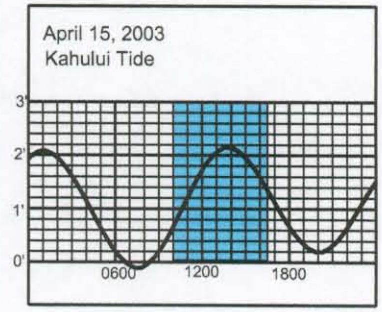
The salinity profiles during the flood stage show this warmer layer to be more saline than the surface layers. This suggests that the surface layer is composed of a mixture of ocean and fresh water from some source within the harbor. It should be noted that the Near Shore Station 1 (NS1) which is located outside the harbor shows similar characteristics suggesting a coastal fresh water source. The salinity variation from surface to bottom is much more evident in the near shore stations on the southern side of the harbor (H5, H6, H7 and H8). The source of this fresh water layer is not currently known. It is not attributed to a local rainfall event as rain did not occur prior to or during this measuring period. It is suggested that it is from a fresh water source located near the shoreline. At stations on the east side of the harbor closer to Pier 1 the variation from surface to bottom is not as wide ranging as the rest of the harbor. This suggests that the fresh water source occurs along the southwestern shoreline of the harbor. The salinity profiles during the ebb stage show the same general results of a less saline layer overlying a more saline layer but with a more pronounced fresher layer of water occurring from the southern part of the harbor towards the mouth. This is especially evident at station H3.

The density profiles (Sigma t) during the flood stage show the water mass to be generally vertically stable throughout the harbor except near the harbor mouth. This suggests a generally stratified water mass throughout most of the harbor with a fresh surface water layer overlying a more saline layer. During the flood stage the profiles near the mouth(NS3 , H1 and H2) suggest that warmer denser saline water enters the harbor below a discharging fresh water layer. This is a typical salt water- fresh water tidal mixing characteristic at narrow openings. The instability shown on the sigma t profiles at NS3 and H1 support this and suggests vertical mixing of the two layers occurs near the mouth of the harbor. The density profiles during the ebb stage suggest the same generally stratified water mass as the flood stage throughout the harbor except that the instability at the mouth of the harbor disappears.

Summary

Surface winds have a major effect on the circulation within the harbor. As shown on a typical strong trade wind day of April 15 the flow in the middle of the harbor tends to flow in the direction of the wind. If the wind is absent then the circulation is tidally driven as shown by the measurements of October 15 and 17 and tends to be counter-clockwise especially in the deeper basin. Near the mouth of the harbor a two layer flow is evident as shown by the drogue results of October 17 and the CTD profiles of April 15 with saline water entering the harbor on a flood tide below a layer of fresher water that is leaving the harbor. The CTD profiles show that fresh water enters the harbor basin from the south western shoreline and mixes with the saline water. The mixing results with a generally stratified water mass throughout the harbor except as noted at the harbor mouth.





April 15, 2003

TIME	Wind Spd	Wind Dir	Weather
(HST)	(knots)	(deg T)	
10:14	20	50	Ptly Cldy
11:35	19	50	Sunny
12:36	21	50	Sunny
13.40	22	50	Ptly Cldy
14:41	23	50	Sunny

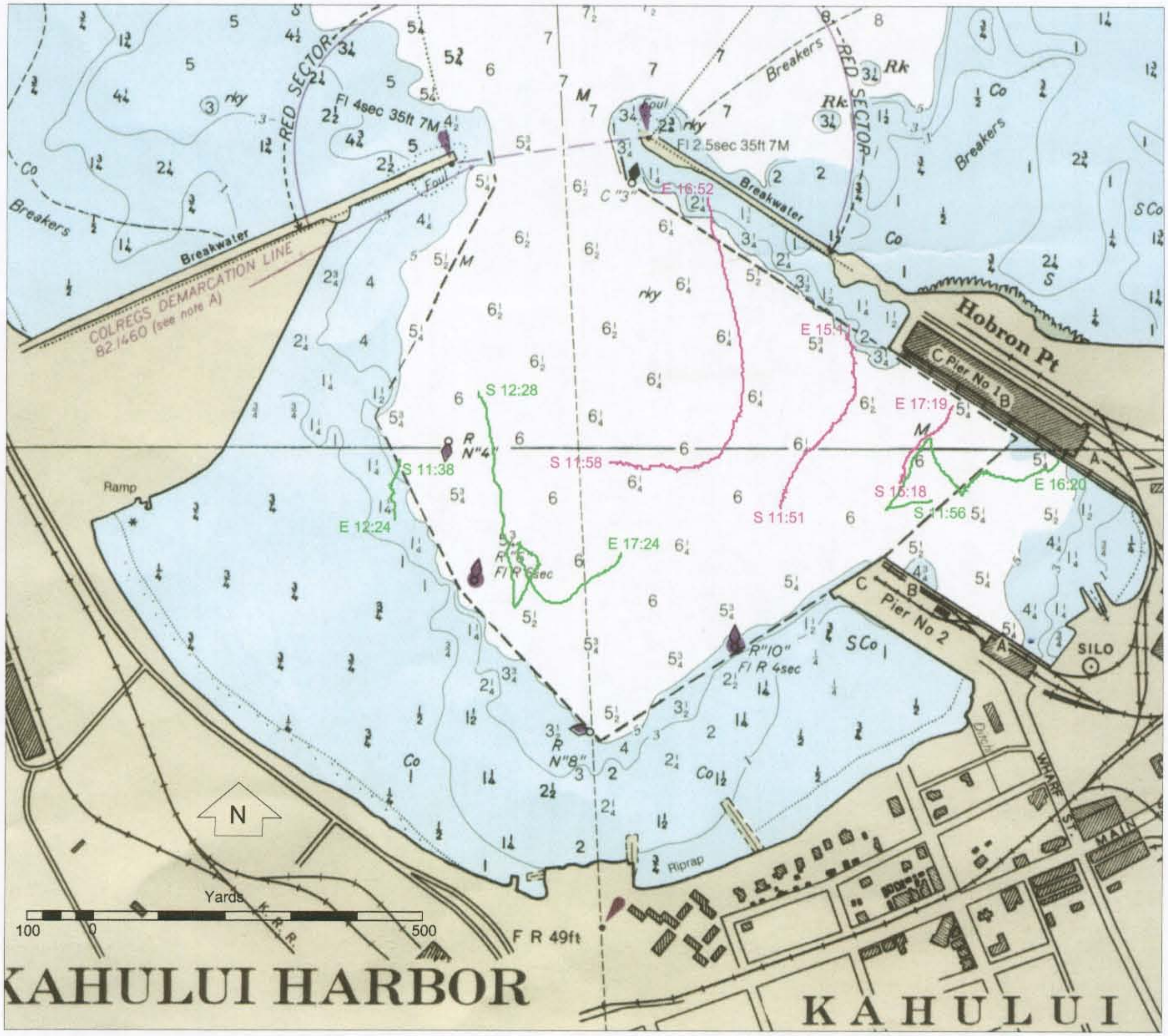
LEGEND

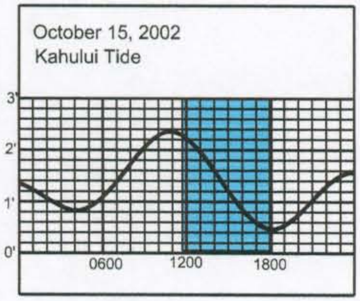
Start Time	Depth	End Time
S 10:00	25 feet	E 12:00
S 10:00	5 feet	E 12:00

Kahului Commercial Harbor
2025 Master Plan EA

Edward K. Noda and Associates, Inc.

Drogue Survey Results
15 April 2003





October 15, 2002

TIME	Wind Spd	Wind Dir	Weather
(HST)	(knots)	(deg T)	
13:13	3	0	Sunny
1349	5	20	Ptly Cloudy
1430	0	0	Cloudy
1439	10	180	Cloudy
1455	5	180	Ptly Sunny
1700	5	180	Ptly Sunny

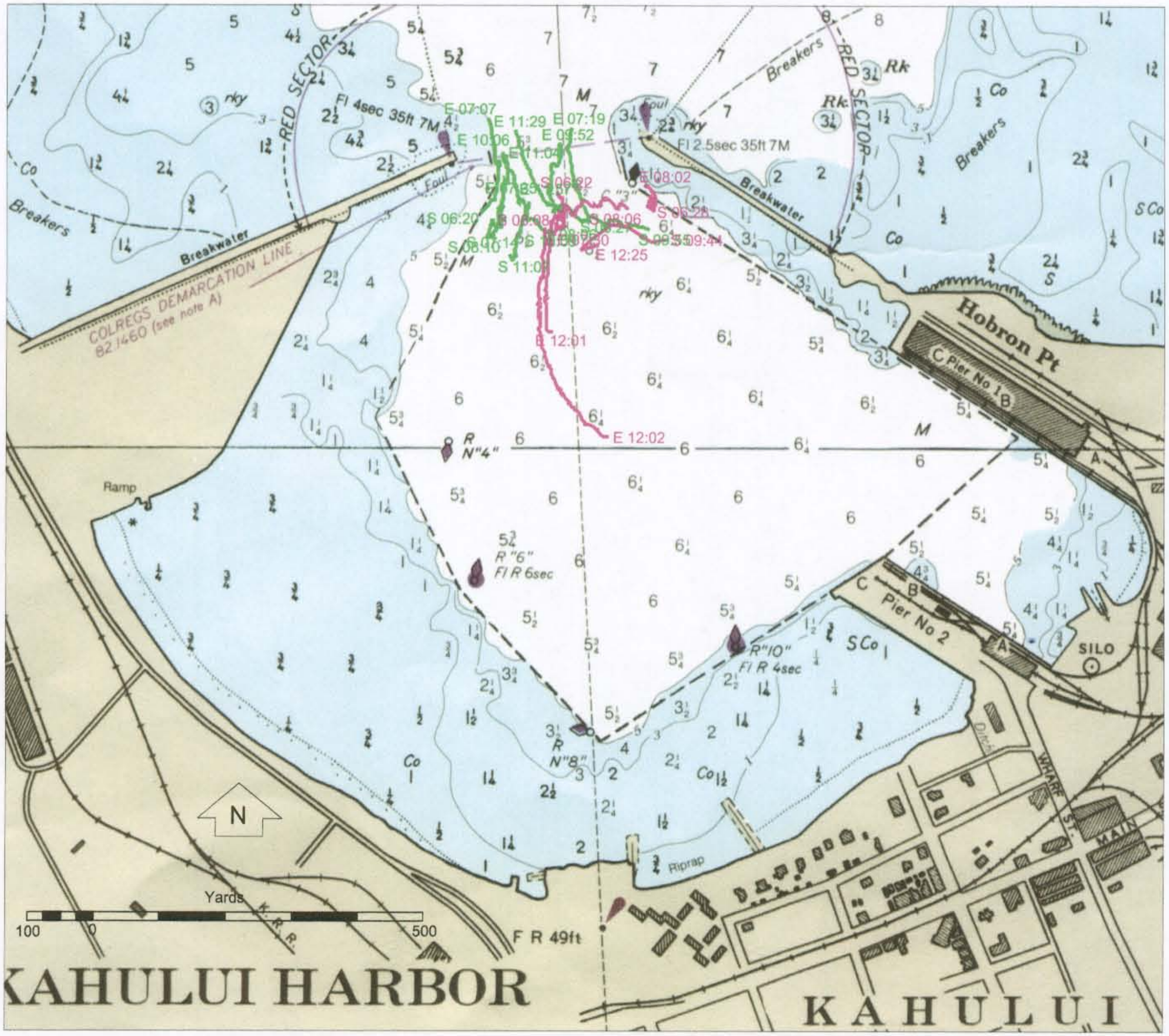
LEGEND

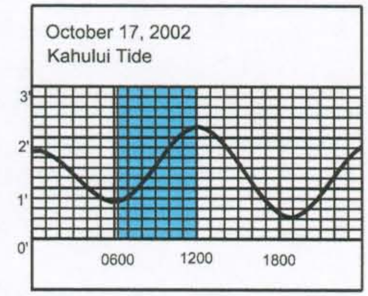
Start Time	Depth	End Time
S 10:00	25 feet	E 12:00
S 10:00	5 feet	E 12:00

Kahului Commercial Harbor
2025 Master Plan EA

Edward K. Noda and Associates, Inc.

Drogue Survey Results
15 October 2002 Ebb Tide





October 17, 2002

TIME	Wind Spd	Wind Dir	Weather
(HST)	(knots)	(deg T)	
06:38	2.5	90	Cldy & Rain
07:41	1	90	Cldy & Rain
10:16	0	0	Cldy & Rain
10:42	0	0	Cldy & Rain
12:00	0	0	Sunny

LEGEND

Kahului Commercial Harbor
2025 Master Plan EA

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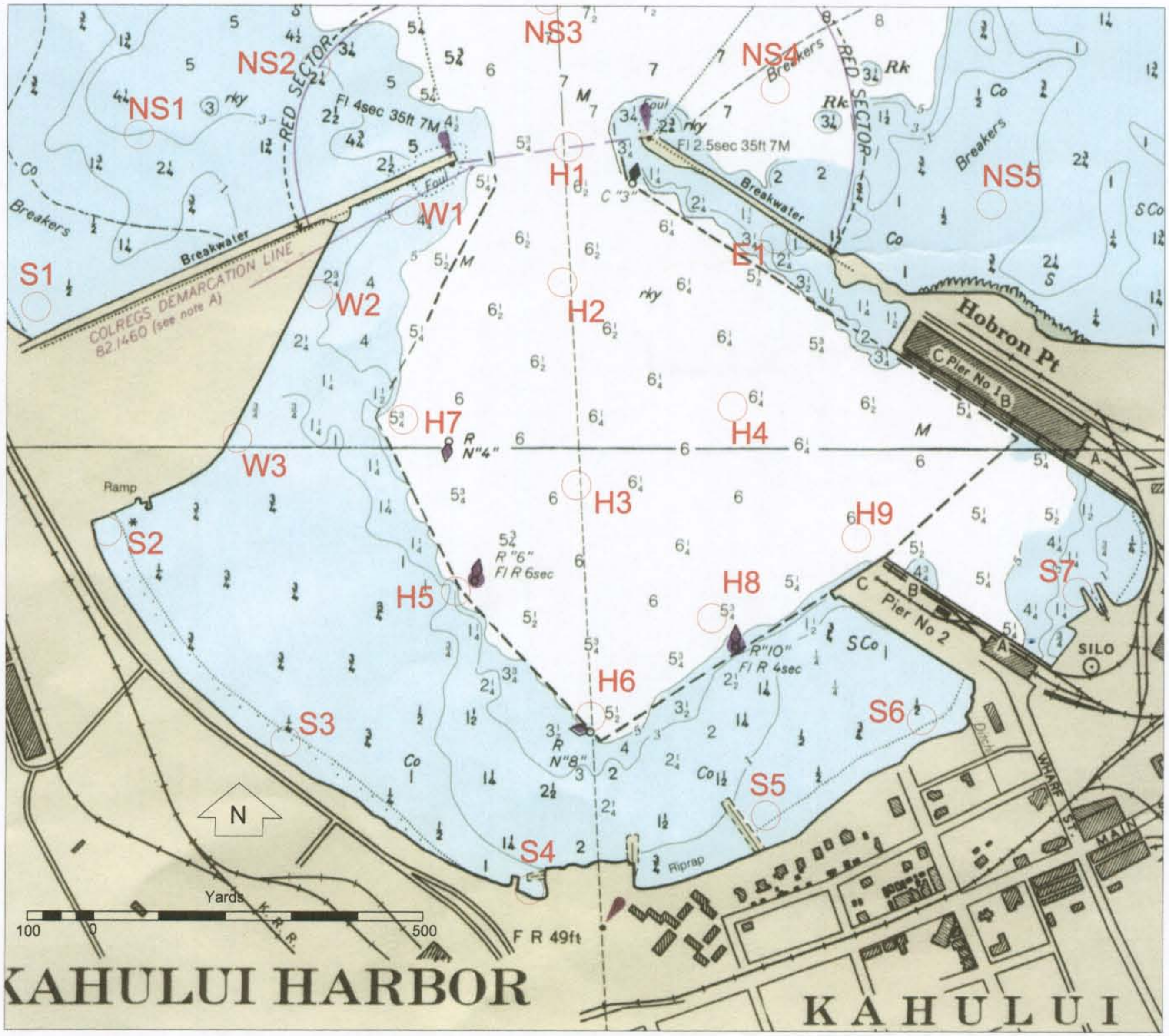
Drogue Survey Results
17 October 2002 Flood Tide



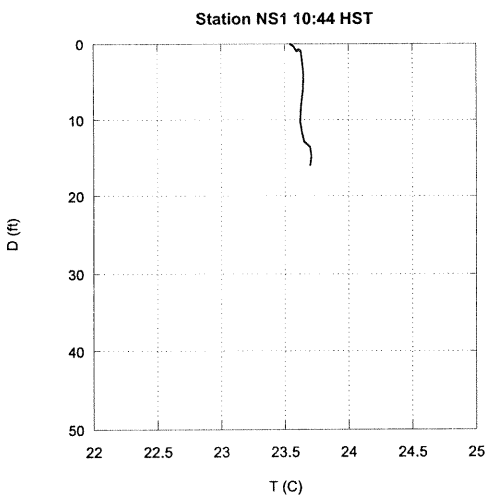
LEGEND

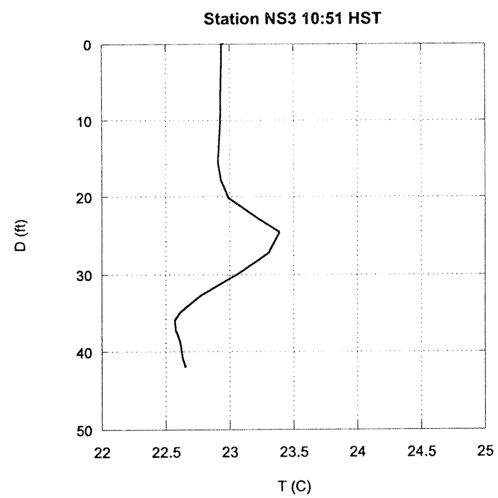
Start Time	Depth	End Time
S 10:00	25 feet	E 12:00
S 10:00	5 feet	E 12:00

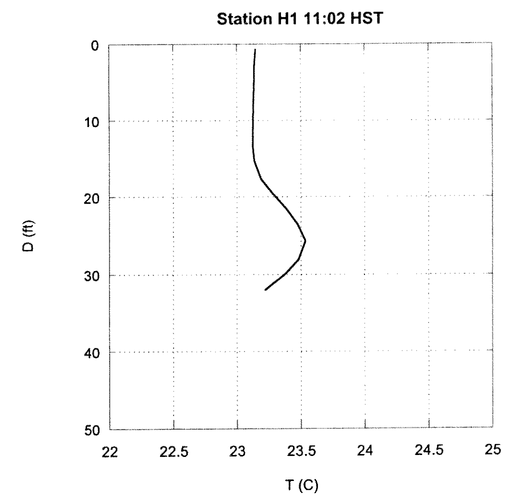
Kahului Commercial Harbor
2025 Master Plan EA

Edward K. Noda and Associates, Inc.

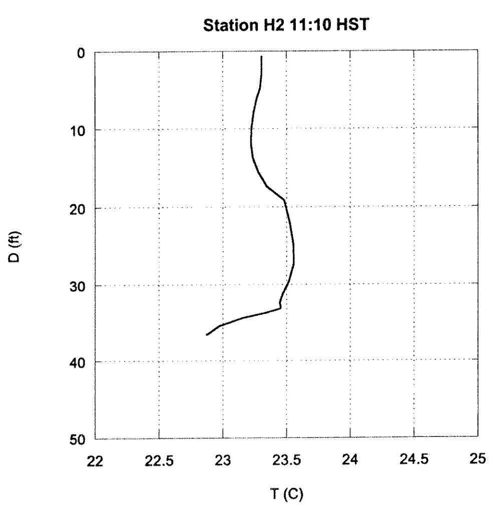
Water Quality Station Locations

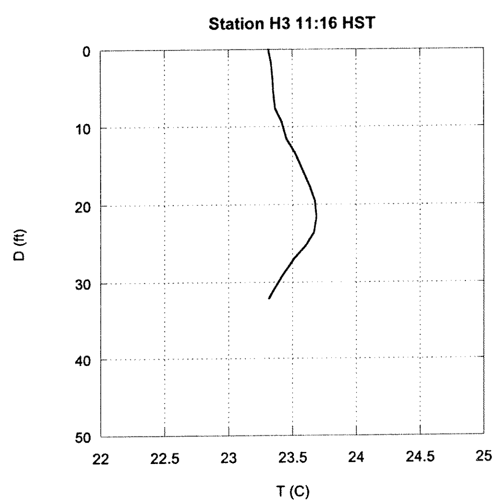


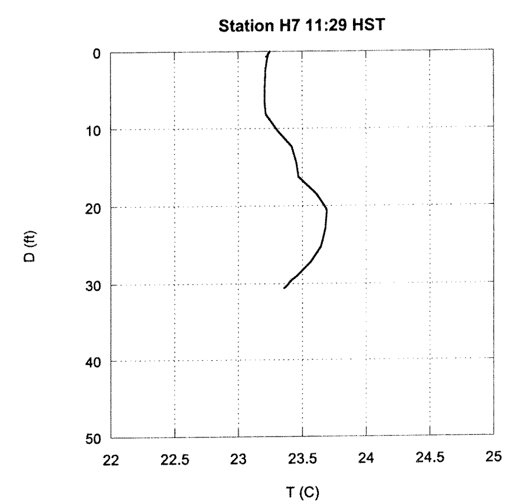




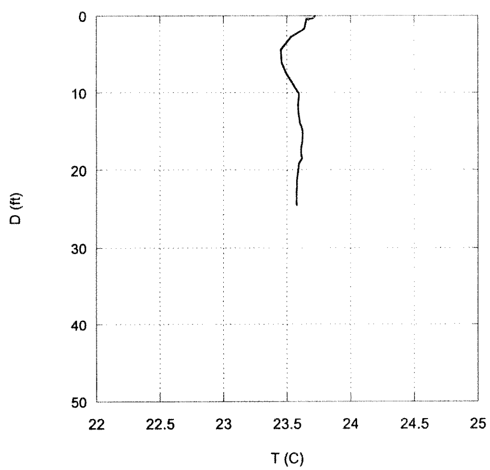
KAHULUI HARBOR TEMPERATURE PROFILES
APRIL 15 2003



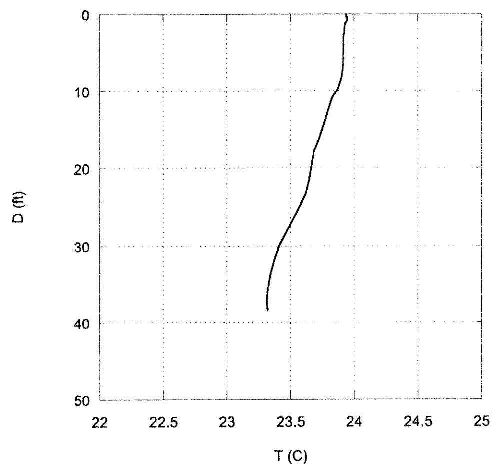




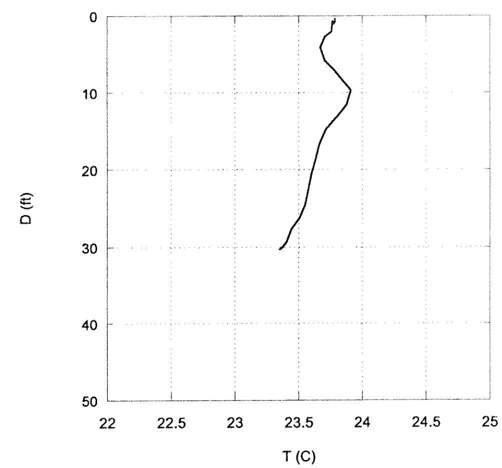
Station E1 11:45 HST



Station H4 11:51 HST

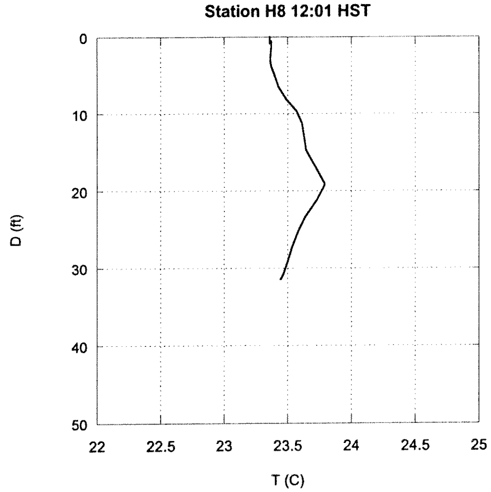


Station H9 11:57 HST

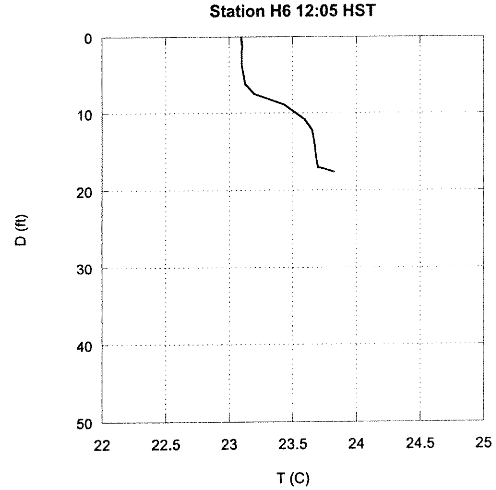


KAHULUI HARBOR TEMPERATURE PROFILES
APRIL 15 2003

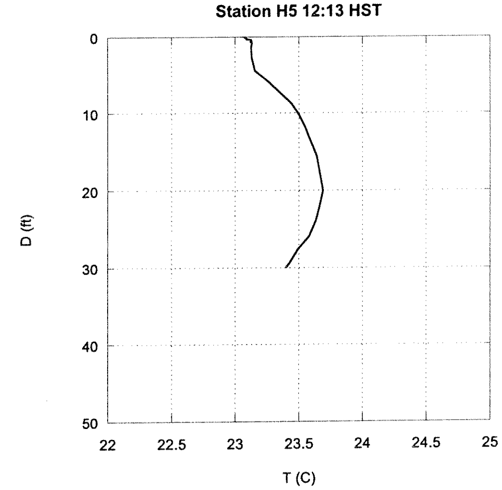
Station H8 12:01 HST

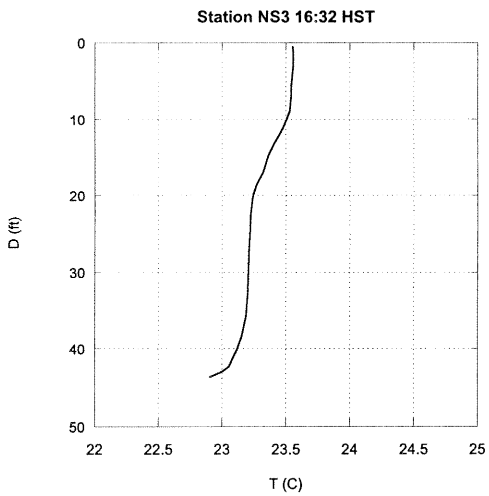


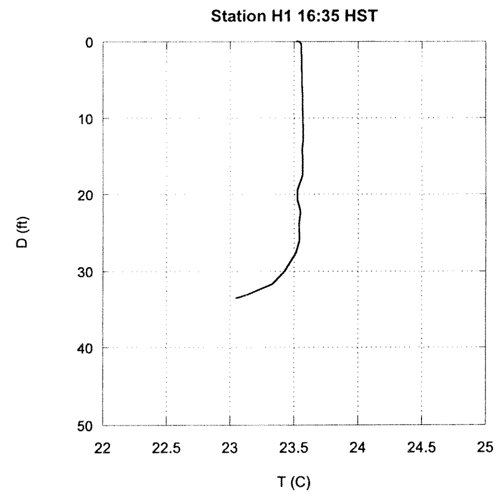
Station H6 12:05 HST

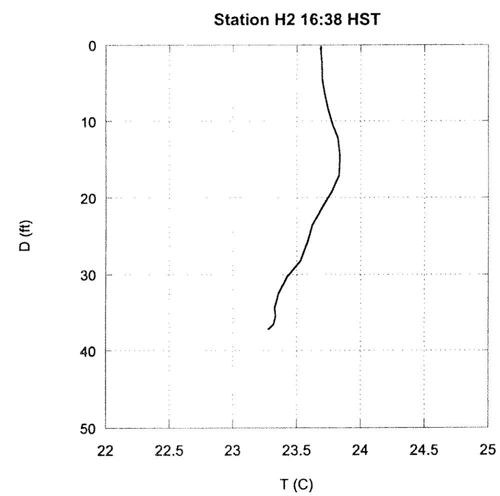


Station H5 12:13 HST









KAHULUI HARBOR TEMPERATURE PROFILES
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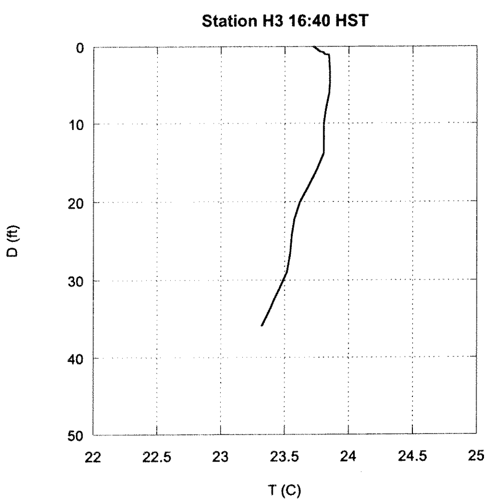
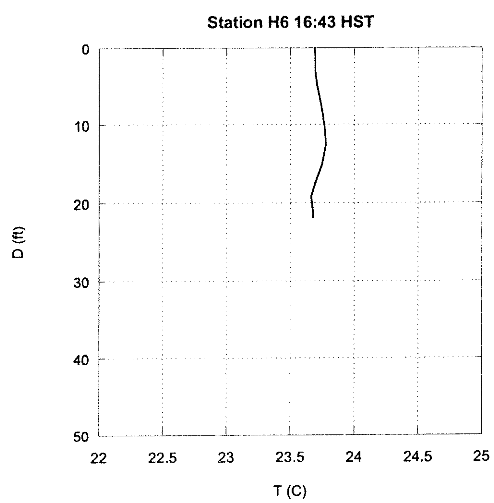
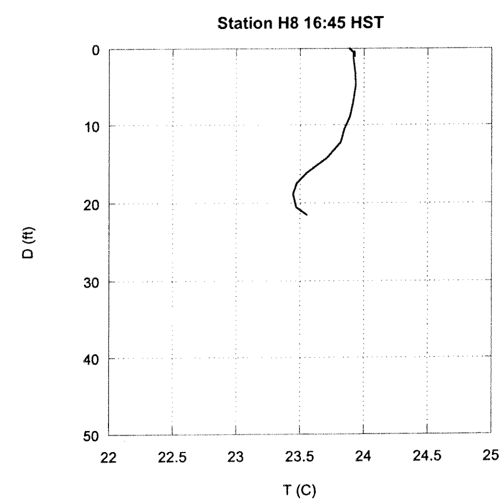
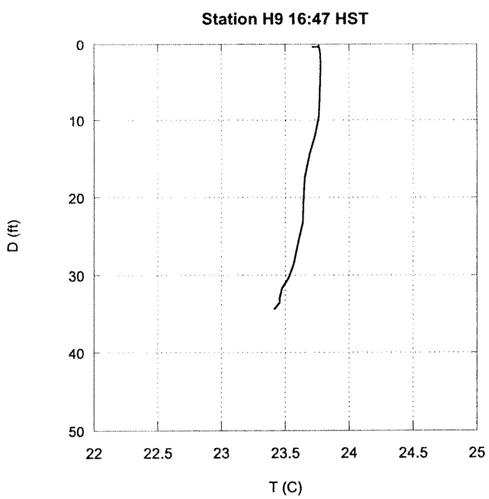
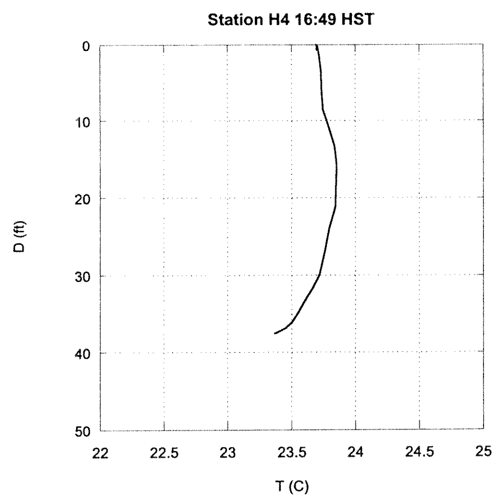
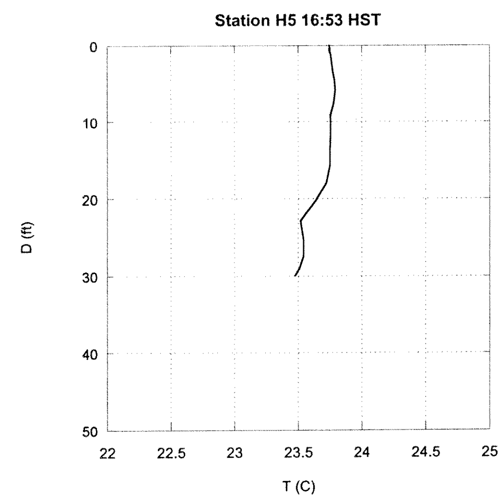




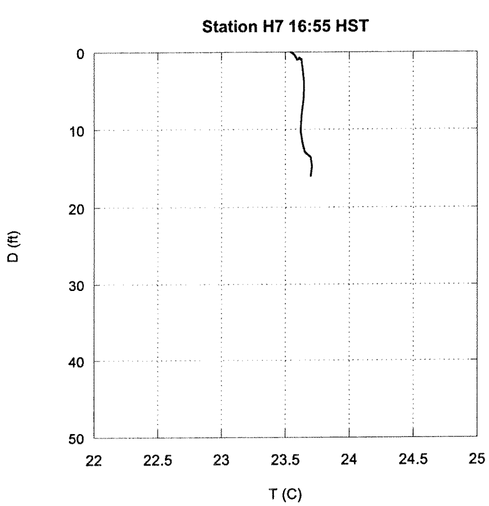


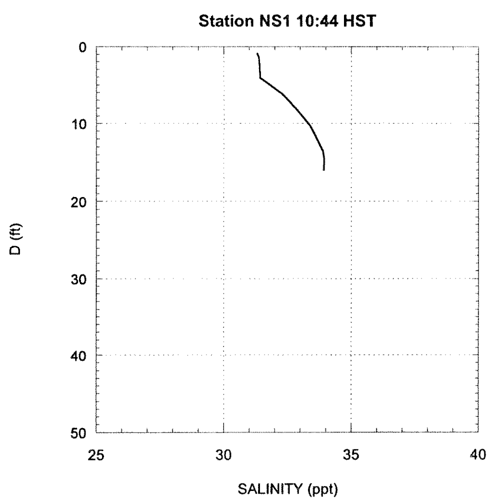


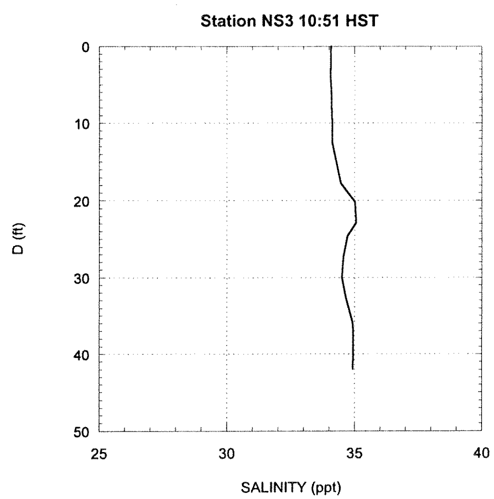


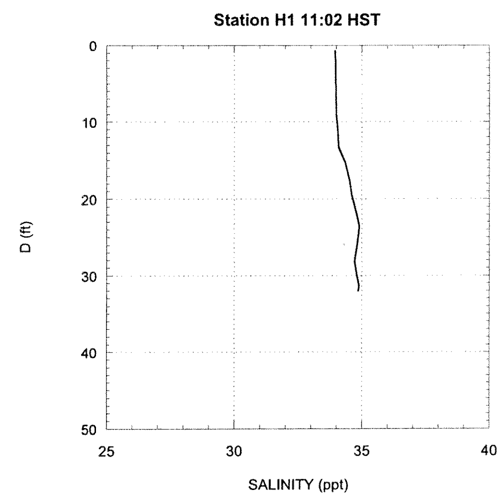


KAHULUI HARBOR TEMPERATURE PROFILES
APRIL 15 2003

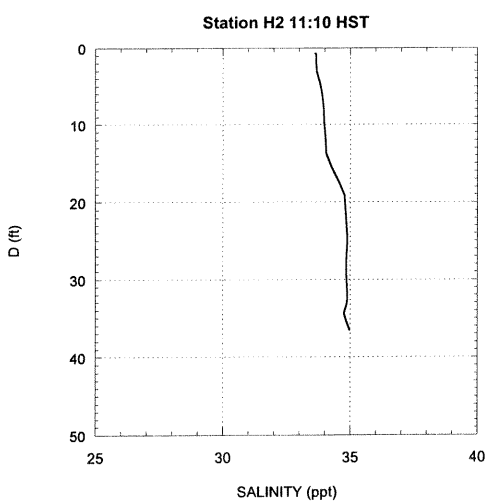


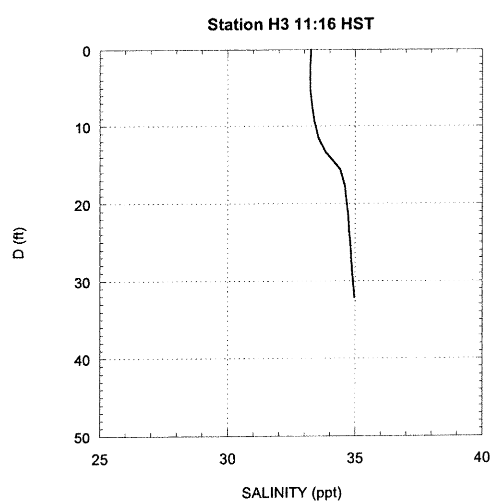


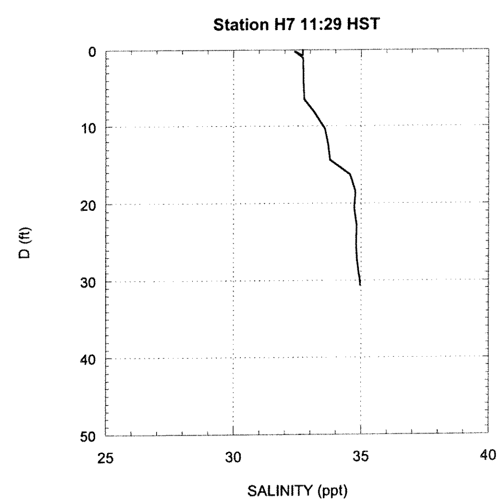


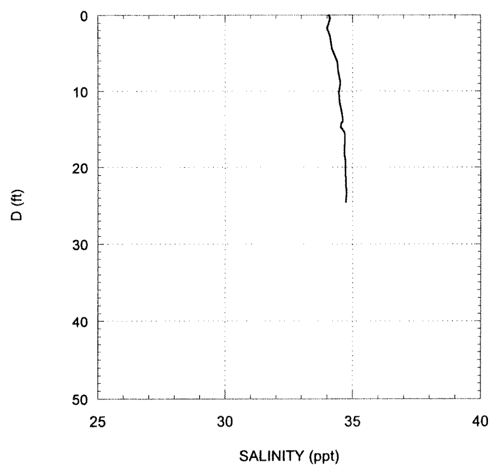


KAHULUI HARBOR SALINITY PROFILES
APRIL 15 2003

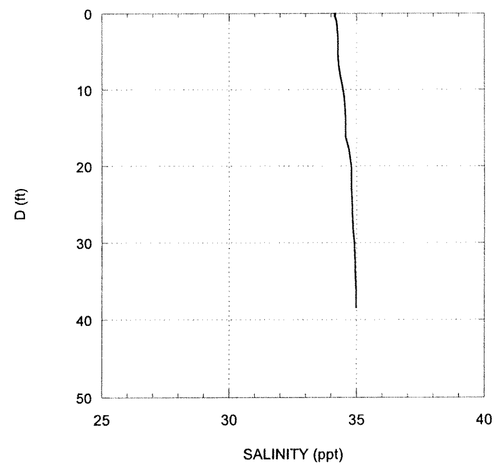




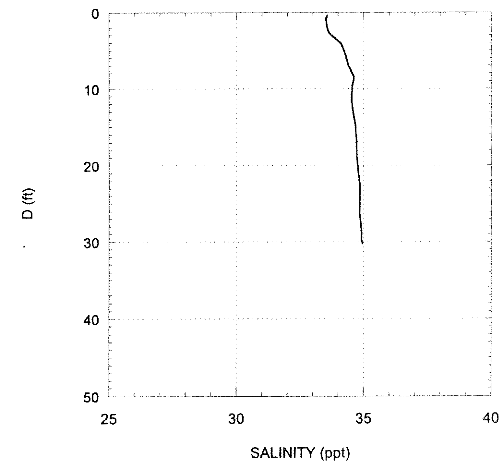




Station E1 11:45 HST

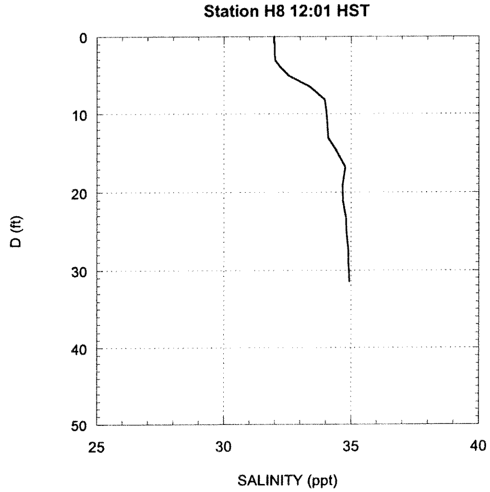


Station H4 11:51 HST

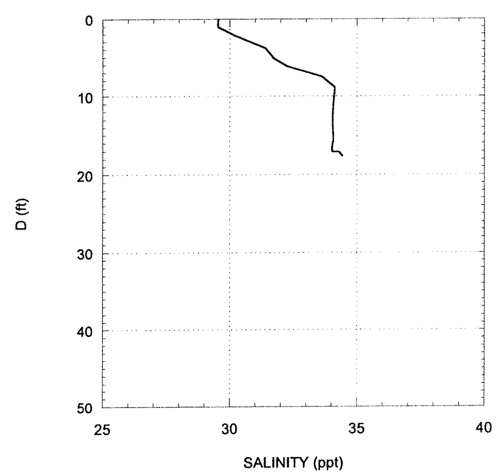


Station H9 11:57 HST

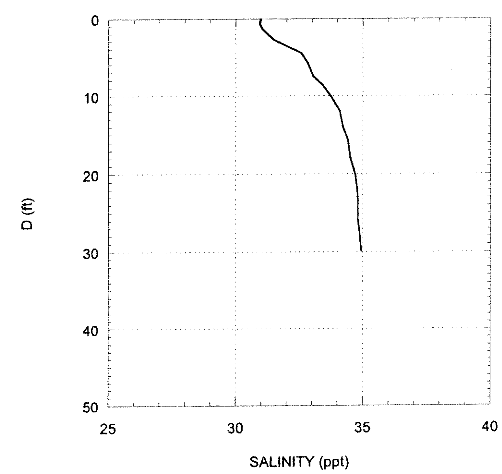
KAHULUI HARBOR SALINITY PROFILES
APRIL 15 2003



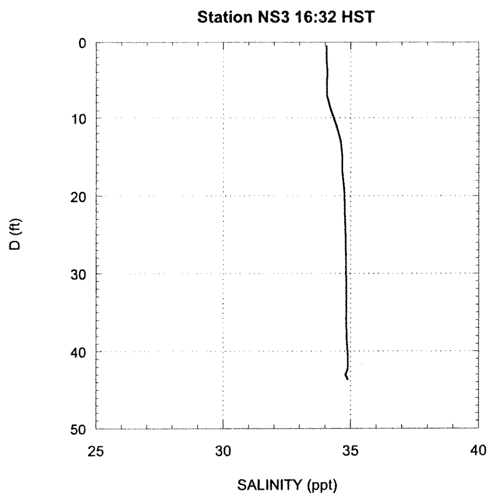
Station H8 12:01 HST

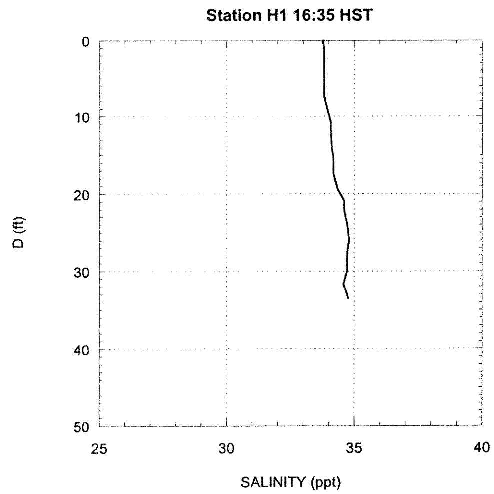


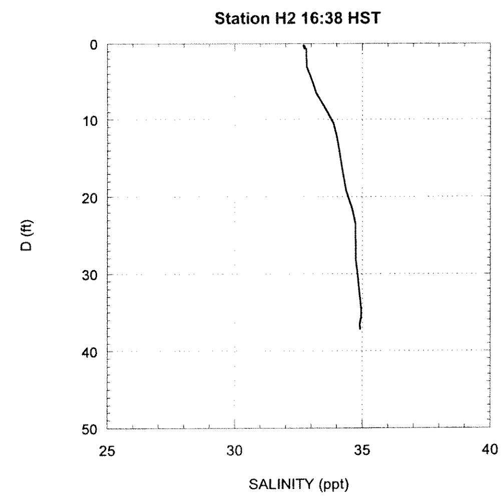
Station H6 12:05 HST



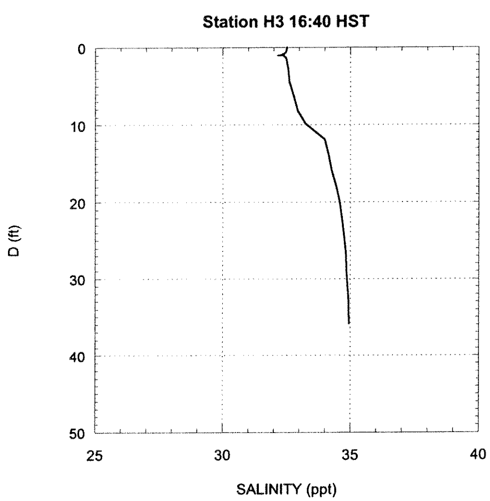
Station H5 12:13 HST

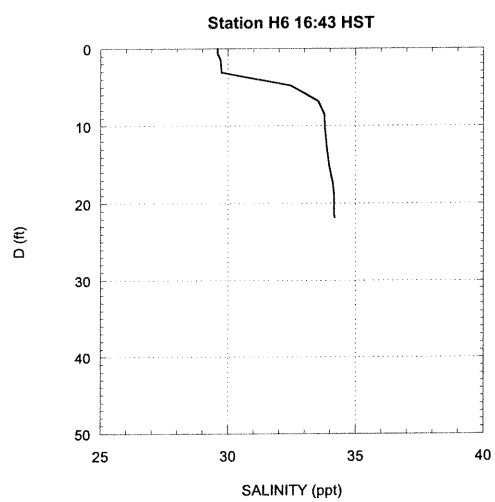


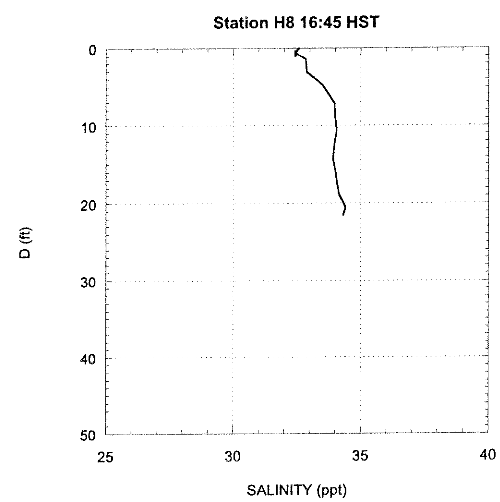


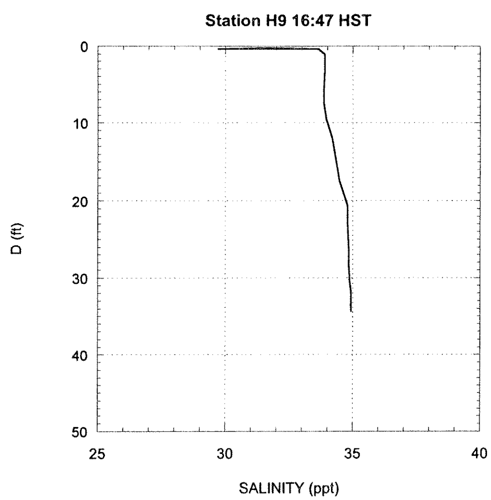


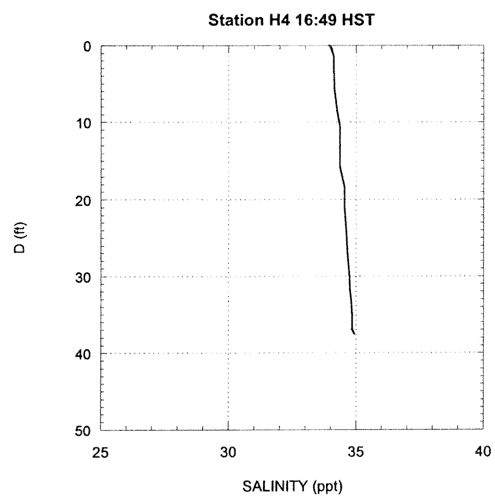
KAHULUI HARBOR SALINITY PROFILES
APRIL 15 2003

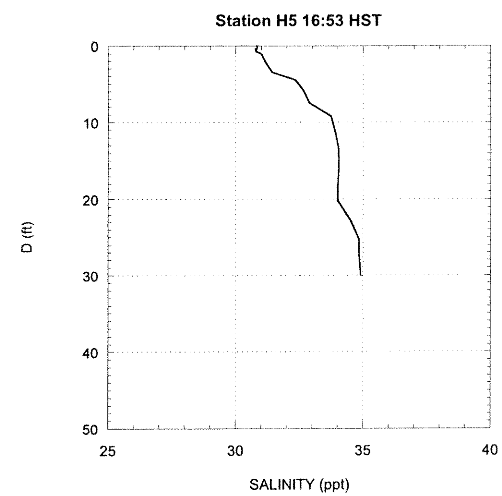




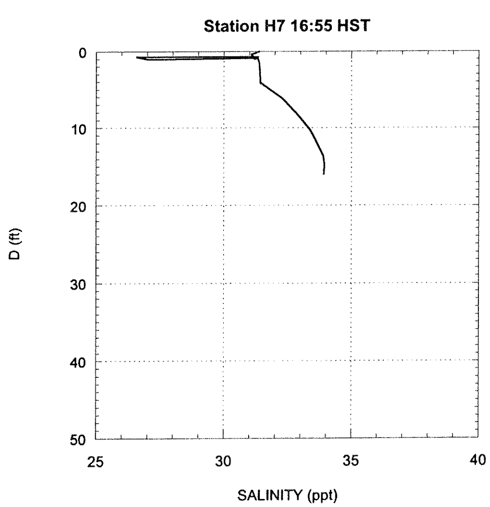




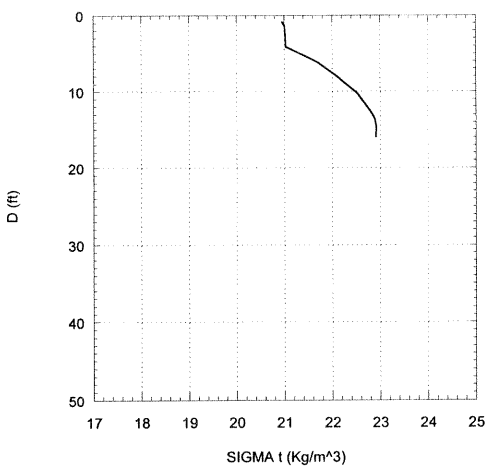




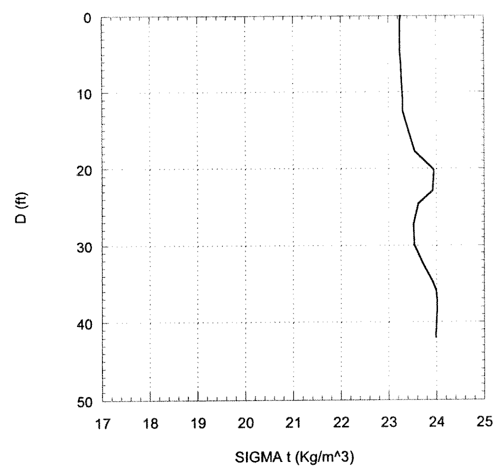
KAHULUI HARBOR SALINITY PROFILES
APRIL 15 2003



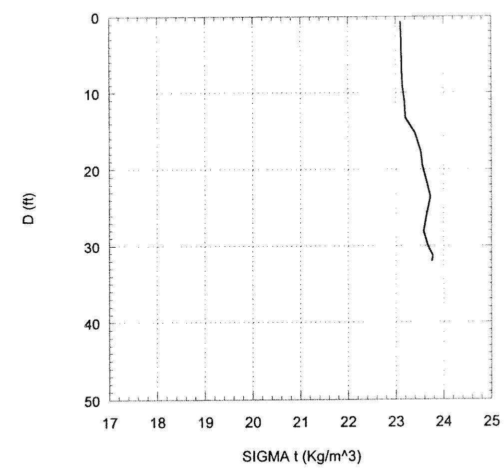
Station NS1 10:44 HST



Station NS3 10:51 HST

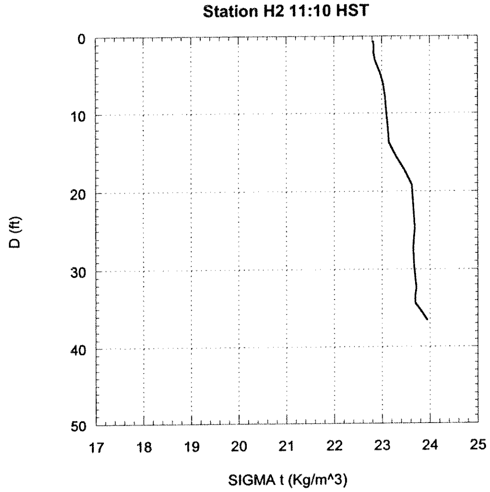


Station H1 11:02 HST

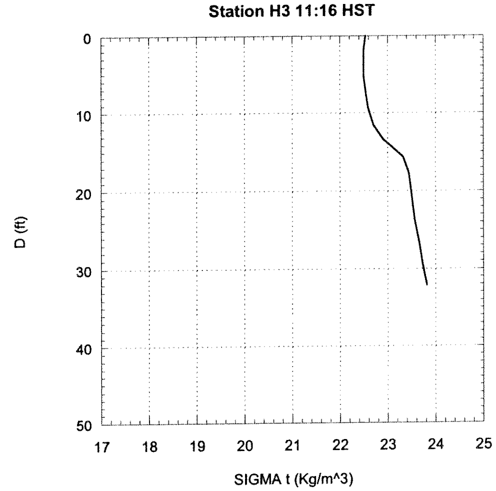


KAHULUI HARBOR SIGMA T PROFILES
APRIL 15 2003

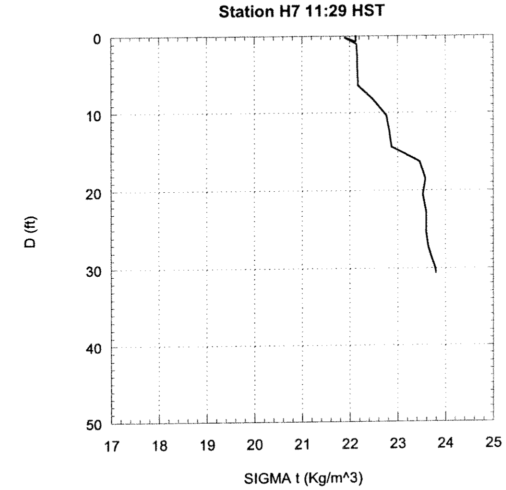
Station H2 11:10 HST

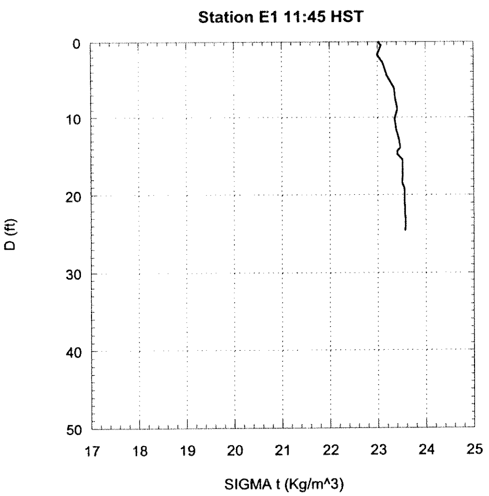


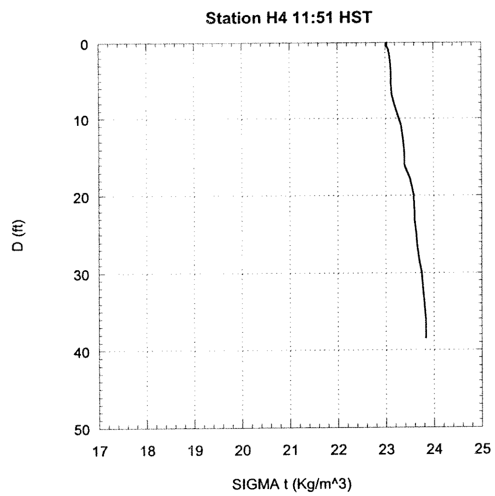
Station H3 11:16 HST

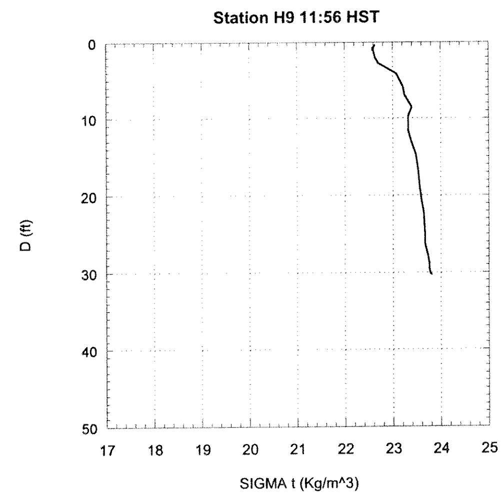


Station H7 11:29 HST

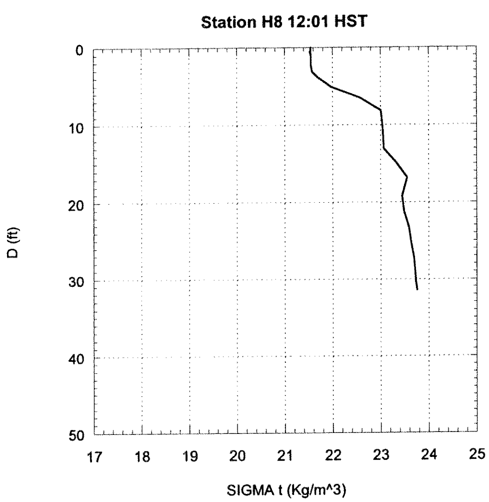


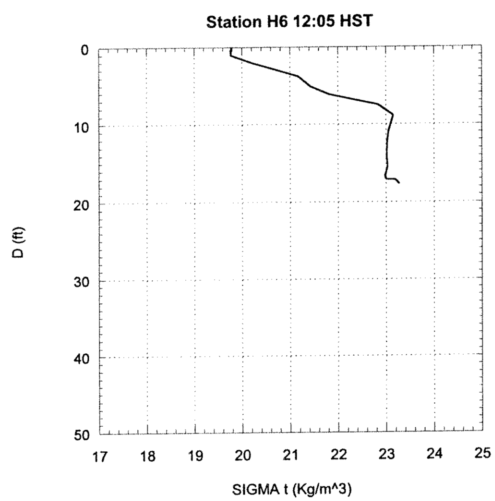


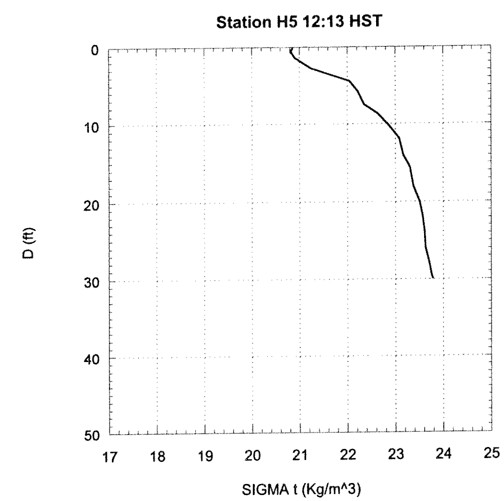




KAHULUI HARBOR SIGMA T PROFILES
APRIL 15 2003







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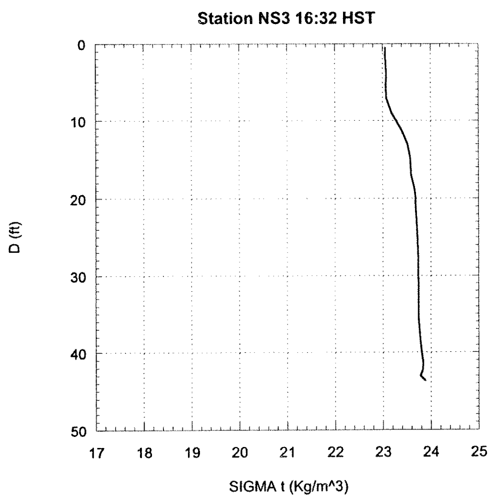

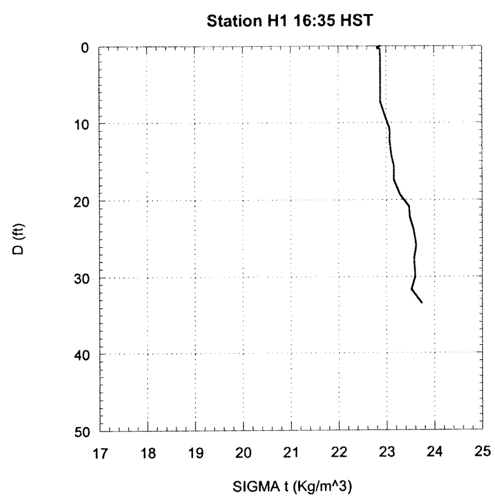

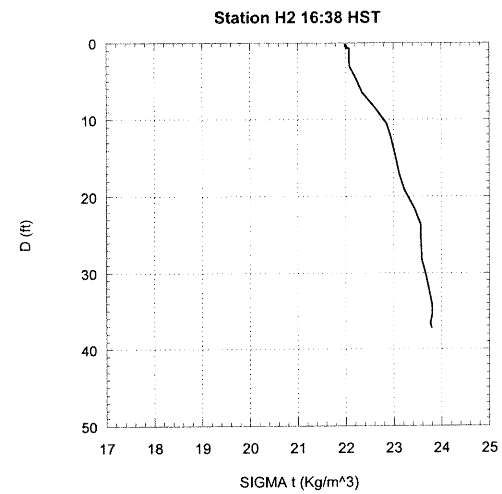

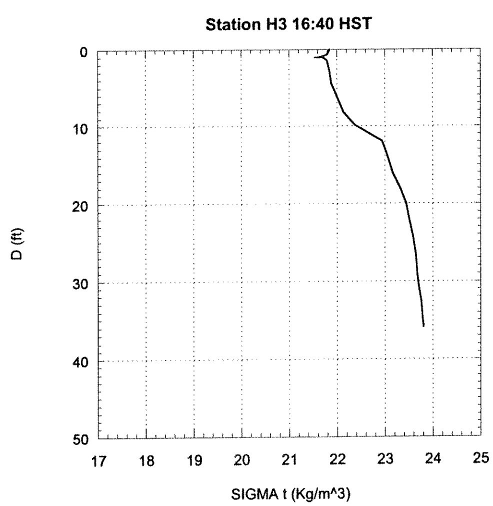

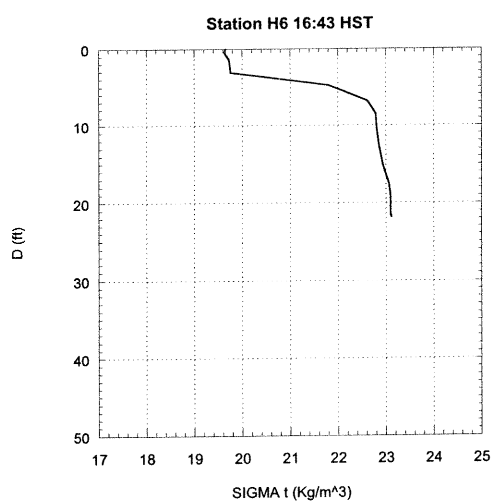

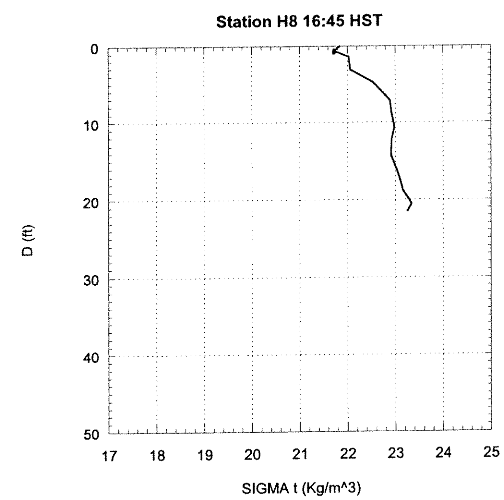

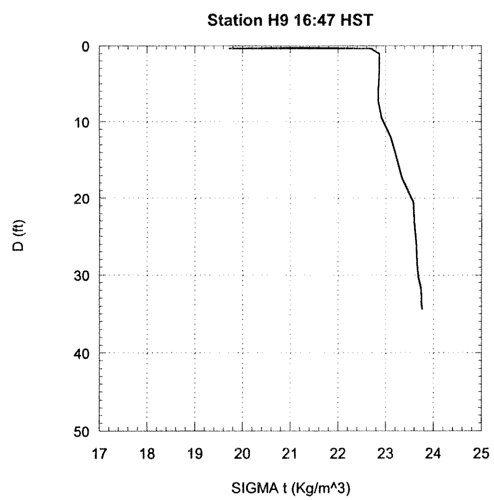

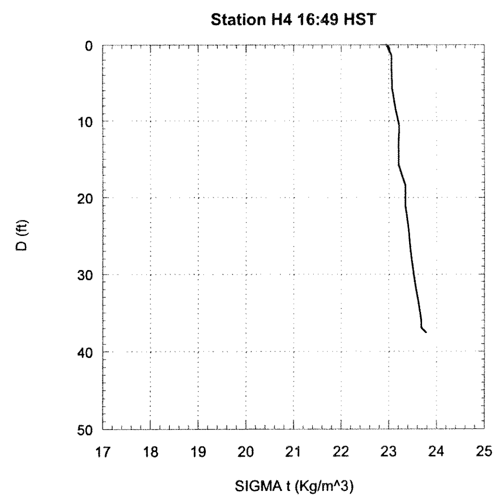

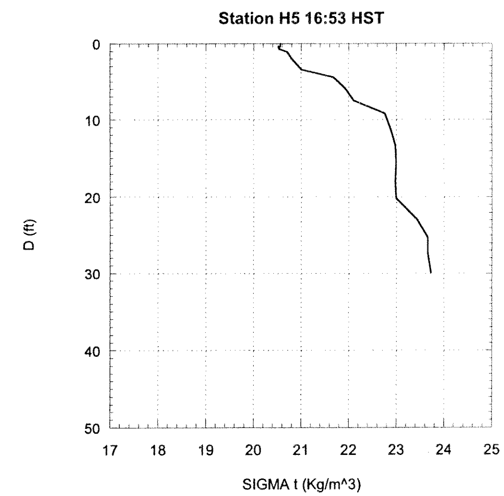

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