

EXHIBIT "A"

MARINE WATER QUALITY MONITORING
MAKENA RESORT, MAKENA, MAUI
WATER CHEMISTRY
REPORT 1-2004

Prepared for

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MAKENA RESORT CORP.

I. PURPOSE

Makena Resort Corp. has constructed two 18-hole golf courses (North and South Courses), a 6-court tennis complex, and a 310-room hotel within the boundaries of the Makena Resort Development. The study area off the Makena site fronts approximately 5.4 miles of coastline. The area is bounded by Papanui Stream (Nahuna Point) on the north and Pu'u Olai (Ahihi Bay) on the south. No part of the project involves direct alteration of the shoreline or nearshore marine environments.

Evaluations of other resort and golf course development located near the ocean in the Hawaiian Islands reveal that while there is detectable input to the coastal ocean of materials used for fertilization of turfgrass, there are few, if any, effects that can be considered detrimental to the marine ecosystem (Dollar and Atkinson 1992). Thus, there is no a priori reason to suspect that the construction and responsible operation of the development at Makena will cause any harmful changes to the marine environment.

Nevertheless, in the interest of assuring maintenance of environmental quality, and as a means of ensuring that proper procedures are set forth, an ongoing marine monitoring program off the Makena Golf Courses was implemented by Makena Resort Corp. in 1995. In 1998 the marine monitoring program became a condition of the State Land Use Commission District Boundary Amendment for the project.

The primary goals of the program are twofold: 1) to assess the degree that material from fertilizers and other materials used on the project leach to groundwater and subsequently reach the ocean, and 2) to determine the fate of these materials within the nearshore zone. In terms of determining fate, the question that is addressed is if the materials that originate from project activities disperse with little or no effect, or do they cause changes in water quality sufficient to alter marine biological community structure?

The rationale of the monitoring program is to conduct repetitive evaluations of water chemistry at the same locations at regular time intervals (twice per year). This strategy allows for determination of variations in effects from the project development in both space (at different locations along the shoreline) and time. These studies also fulfill condition No. 10, Declaration of Conditions pertaining to the Amendment of the District Boundary, as required by the Land Use Commission, dated April 17, 1998. The following report presents the results of the thirteenth increment in the monitoring program, and contains data from water chemistry sampling conducted on March 6, 2004.

II. ANALYTICAL METHODS

Three survey sites directly downslope from the Makena Golf Course site have been selected as sampling locations. A fourth site, located offshore of an area with minimal land-based

development, particularly golf course operations, was selected as a control. Figure 1 is a map showing the shoreline and topographical features of the Makena area, and the location of the North and South Golf Courses. The four survey sites are depicted as transects perpendicular to the shoreline extending from the shoreline out to what is considered open coastal ocean (i.e., beyond the effects of activities on land). Survey Site 1 is located near the northern boundary of the project site off Nahuna Point; Survey Site 2 bisects the area off the center of the North course near Makena Landing. Site 3 bisects the middle of the South course near Maluaka Point. Site 4 (Control) is located at the northern boundary of the 'Ahihi-Kina'u natural area reserve offshore of the 1790 lava flow and approximately 1-2 miles south of the existing Makena Golf courses (Figure 1).

In 2003, Site 3 was relocated from a location at the southern boundary of the project offshore of Oneloa Beach to the location directly off the golf course described above. Site 3 was relocated because the original location consistently showed virtually no input of groundwater to the ocean, hence offered little potential for evaluating effects from the project. The new location of Site 3 is directly downslope of the portion of the golf course nearest to the ocean. As a result it provides a better representation of influence of the golf course on nearshore water quality. Several private residences are located near the shoreline in the vicinity of Site 4. Land use upslope of the survey site consists primarily of cattle grazing. All fieldwork was conducted on March 6, 2004 using a small boat. Environmental conditions during sample collection consisted of calm seas, mild winds (10-15 knots) and sunny skies. Water samples were collected at stations along transects that extend from the highest wash of waves to approximately 125-200 meters (m) offshore at each site. Such a sampling scheme was designed to span the greatest range of salinity with respect to freshwater efflux at the shoreline. Sampling was more concentrated in the nearshore zone because this area is most likely to show the effects of shoreline modification. With the exception of the two stations closest to the shoreline (0 and 2 m offshore), samples were collected at two depths; a surface sample was collected within approximately 10 centimeters (cm) of the sea surface, and a bottom sample was collected within one m of the sea floor.

Water samples beyond 10 meters (m) from the shoreline were collected using a 1.8-liter Niskin-type oceanographic sampling bottle. This bottle was lowered to the desired depth in an open position where spring-loaded endcaps were triggered to close by a messenger released from the surface. Upon recovery, each sample was transferred into a 1-liter polyethylene bottle until further processing. For nearshore samples within 10 m of the shoreline, water samples were collected in 1-liter polyethylene bottles by divers swimming from the boat.

Water samples were also collected from seven golf course irrigation wells (No's 1, 2, 3, 4, 5, 6, and 10) on March 17, 2004. Six 18" suction lysimeters have been recently installed at various locations on the golf courses. These devices consist of a hollow Plexiglas tube with the bottom several inches consisting of semi-permeable sintered glass. When a vacuum is applied to the tube through a manual vacuum pump, water in the soil surrounding the tube is drawn into the collection tube. The semi-permeable nature of the sintered glass prevents

passive infiltration of water into the tube, insuring that sample water consists only of material that is collected at the time when the vacuum suction is applied. Five lysimeters were sampled on March 17, 2004, with two yielding water (Holes 3 and 15 on the South course). The lack of water yield from lysimeters does not indicate malfunctioning of the devices, but rather that irrigation water did not penetrate the turf layer to the depth of water collection (~18") during the period when vacuum suction is applied.

Subsamples for nutrient analyses from all water sources were immediately placed in 125-milliliter (ml) acid-washed, triple rinsed, polyethylene bottles and stored on ice until returned to Honolulu. Water for other analyses was subsampled from 1-liter polyethylene bottles and kept chilled until analysis.

Water quality parameters evaluated included the 10 specific criteria designated for open coastal waters in Chapter 11-54, Section 06 (Open Coastal waters) of the Water Quality Standards, Department of Health, State of Hawaii. These criteria include: total nitrogen (TN) which is defined as dissolved inorganic nitrogen plus dissolved organic nitrogen, nitrate + nitrite nitrogen ($\text{NO}_3^- + \text{NO}_2^-$, hereafter referred to as NO_3^-), ammonium (NH_4^+), total phosphorus (TP) which is defined as dissolved inorganic phosphorus plus dissolved organic phosphorus, chlorophyll *a* (Chl *a*), turbidity, temperature, pH and salinity. In addition, orthophosphate phosphorus (PO_4^{3-}) and silica (Si) were reported because these constituents are sensitive indicators of biological activity and the degree of groundwater mixing, respectively.

Analyses for NO_3^- , NH_4^+ and PO_4^{3-} , and were performed using a Technicon autoanalyzer according to standard methods for seawater analysis (Strickland and Parsons 1968, Grasshoff 1983). TN and TP were analyzed in a similar fashion following digestion. Dissolved organic nitrogen (TON) and dissolved organic phosphorus (TOP) were calculated as the difference between TN and inorganic N, and TP and inorganic P, respectively. Limits of detection for the dissolved nutrients are $0.01 \mu\text{M}$ ($0.14 \mu\text{g/L}$) for NO_3^- and NH_4^+ , $0.01 \mu\text{M}$ ($0.31 \mu\text{g/L}$) for PO_4^{3-} , $0.1 \mu\text{M}$ ($1.4 \mu\text{g/L}$) for TN and $0.1 \mu\text{M}$ ($3.1 \mu\text{g/L}$) for TP.

Chl *a* was measured by filtering 300 ml of water through glass fiber filters; pigments on filters were extracted in 90% acetone in the dark at -5°C for 12-24 hours, and the fluorescence before and after acidification of the extract was measured with a Turner Designs fluorometer (level of detection $0.01 \mu\text{g/L}$). Salinity was determined using an AGE Model 2100 laboratory salinometer with a precision of 0.0003‰.

In-situ field measurements included water temperature and pH using a Fisher Accumet Model AP61 field meter with a readability of 0.01°C and 0.01 pH units. Turbidity was determined in the field using a DRT-13CE field meter, and reported in nephelometric turbidity units (NTU). Nutrient, turbidity, Chl *a* and salinity analyses were conducted by Marine Analytical Specialists located in Honolulu, Hawaii. This laboratory possess the appropriate acceptability ratings from the State of Hawaii Dept. of Health, and the U.S. EPA

III. RESULTS

A. Horizontal Stratification

Table 1 shows results of all marine water chemical analyses for samples collected off Makena on March 6, 2004 reported in micromolar units μM). Table 2 shows similar results presented in units of micrograms per liter $\mu\text{g/L}$). Tables 3 and 4 show geometric means of ocean samples collected at the same sampling stations during the thirteen surveys to date from August 1995 to March 2004. Table 5 shows water chemistry measurements (in units of μM and $\mu\text{g/L}$) for samples collected from irrigation wells and the lysimeters located on the Makena Resort Golf Courses. Concentrations of twelve chemical constituents in surface and deep-water samples from the March 2004 sampling are plotted as functions of distance from the shoreline in Figures 2 and 3. Mean concentrations (\pm standard error) of twelve chemical constituents in surface and deep water samples from the entire sampling program at Makena Resort, as well as data from the most recent sampling, are plotted as functions of distance from the shoreline in Figures 4-15.

At all four sites there are elevated concentrations of dissolved Si, NO_3^- , PO_4^{3-} and TN, and decreased salinity within a zone extending from the highest wash of waves to a distance of approximately 50 -150 m offshore (Figures 2-3, 4-12, Tables 1 and 2). The greatest changes in the concentrations of dissolved Si, NO_3^- , TN and salinity with respect to distance from the shoreline were evident at Sites 1 and 4 where NO_3^- decreased by one to two orders of magnitude and salinity increased by 9.1‰ and 2.7‰, respectively, between the shoreline and 150 m offshore (Tables 1 and 2, Figures 2-3, 4, 6, 13 and 15).

The pattern of elevated Si, NO_3^- , PO_4^{3-} and TN with corresponding low salinity is indicative of groundwater entering the ocean near the shoreline. Low salinity groundwater, which contains high concentrations of Si, NO_3^- , PO_4^{3-} and TN (see values for well waters in Table 5), often percolates to the ocean near the shoreline, resulting in a distinct zone of mixing in the nearshore region. In the Kihei-Makena area, the zone of mixing generally extends to about 100 m of the shoreline. In March 2004, Sites 1 and 4 had more pronounced horizontal gradients in the nearshore mixing zone than Sites 2 and 3 (Tables 1 and 2). With the exception of NO_3^- at Site 1, the relative magnitude in concentrations of these constituents was the same at all four sites beyond 50 - 100 m of the shoreline (Figures 2 and 3). During the March 2004 survey, NO_3^- concentrations at Site 1 were distinctly higher throughout the sampling transect compared to the other three sites (Figure 2, Tables 1 and 2).

Dissolved nutrient constituents that are not associated with groundwater input (NH_4^+ , TON, TOP) showed variable results. With the exception of the shoreline sample at Site 1 that had an elevated concentration of NH_4^+ ($1.32 \mu\text{M}$), surface concentrations of NH_4^+ were nearly constant along the length of each transect (Figures 2, 4, 7, 10 and 13, Tables 1 and 2). Concentrations of TON were also essentially constant along the entire length of each transect (Figure 2). TOP in surface waters was also unchanging at Sites 2, 3 and 4, however, at Site

1, TOP showed decreased levels in the samples collected near the shoreline (Figures 2 and 5, Tables 1 and 2).

Surface concentrations of turbidity and Chl *a* were highest near the shoreline and decreased with increasing distance offshore at all four sites (Figures 3, 6, 9, 12, 15). Turbidity at Sites 1-3 showed similar trends. However, the gradient was not as distinct as with Chl *a*. Among the four sites, values for turbidity were highest at Sites 2 and 3 (Tables 1 and 2).

Approximately two months prior to the December 1999 survey, a severe flash flood originating in the ranch lands upslope of the project site traversed through the golf courses and entered the ocean at Makena Landing. Four years after the event, turbidity values at Site 2 are still somewhat elevated compared to the other three sites. However, after the extended period of time since the storm event the elevated turbidity at Site 2 is most likely not the remnants of the storm runoff within the semi-enclosed embayment. Rather, the floor of the embayment where Site 2 is located consists of a sandy/silt bottom rather than the hard bottom that comprises the other three sampling sites. As a result, under natural conditions it is expected that the turbidity of the water column at Site 2 would be somewhat higher than the other areas simply as a result of resuspension of naturally occurring sediment that comprises the floor of the embayment. It is important to note that in surveys conducted since July 2002, water clarity at Makena Landing had improved greatly compared to preceding surveys in 2001.

Surface water temperature was unavailable in the samples collected within 5 m of the shoreline during the March 2004 survey. Beyond 5 m from the shoreline temperature increased with increasing distance offshore (Figures 3, 6, 9, 12 and 15). The maximum variation in temperature along any transect was 0.4 °C (Tables 1 and 2). Temperature ranged between 24.6 °C and 25.0 °C and temperatures at Site 4 were slightly cooler compared to the other three sites.

B. Vertical Stratification

In many areas of the Hawaiian Islands, input of low salinity groundwater to the nearshore ocean creates a distinct buoyant surface lens that persists for some distance from shore. Buoyant surface layers are generally found in areas where turbulent processes (primarily wave action) are insufficient to completely mix the water column in the nearshore zone. Figures 2 -15 and Tables 1 and 2 show concentrations of water chemistry constituents with respect to vertical stratification. During the March 2004 survey, vertical stratification was evident at Sites 1 and 2 along the entire length of each transect (Figures 2, 3 Tables 1 and 2). Vertical gradients were not distinctly evident beyond 10 m from the shoreline at the other two sites during the March 2004 survey. Physical processes associated with wind and waves were sufficient to mix the water column in the nearshore zone at these sites.

With respect to the other constituents measured, there were variations between surface and deep samples, however, the differences were small and no apparent trend with distance offshore was evident (Figures 2-15).

C. Temporal Comparison of Monitoring Results

Figures 4-15 show mean concentrations ("standard error) of water chemistry constituents from surface and deep samples at all four sites during the thirteen monitoring surveys conducted from 1995 to 2004. In addition, the results of the most recent survey also shown. Examination of the plots in Figures 4-15 reveals some noticeable changes in water chemistry over time. With respect to groundwater efflux, similar patterns of decreasing concentrations of Si, NO_3^- , PO_4^{3-} and increasing salinity with distance from shore are evident in the mean values at Sites 1, 2 and 4 (Figures 4- 9 and 13-15). At Site 3, mean concentrations of Si, NO_3^- , PO_4^{3-} , TN are highest at the sampling station 2 m from the shoreline, while salinity is fairly constant along the length of the transect (Figure 10 - 12). With the exception of Site 1, the concentrations of these nutrients were not elevated in the most recent survey relative to the mean values of the entire sampling set. Such an observation indicates that at Sites 2-4 groundwater discharge, as well as the activities on land that might affect the composition of this discharge, have not changed noticeably over the course of monitoring.

At Site 1 the situation is somewhat different. Concentrations of dissolved nutrients in the samples collected closest to the shoreline during the most recent survey are noticeably higher than the mean values of the overall data set (Figures 4 and 5). This result could indicate a change in input of nutrient subsidies from land that enter the ocean at the shoreline of Site 1. However, the concentration of Si is also elevated at the shoreline at Site 4 relative to the mean concentrations (Figure 4). As Si is not a component of fertilizers or sewage, but does occur in relatively high concentrations in ocean water, it would be expected to remain within the envelope of mean values if a subsidy of nutrients was occurring. Hence, the elevation of Si as well as other dissolved nutrients at the shoreline of Site 1 does not indicate a subsidy of fertilizer nutrients, but rather an anomalously high component of groundwater entering the ocean at Site 1 during the most recent survey relative to past surveys. Beyond the distance from shore where nutrient and salinity gradients flattened out (generally at 10-50 m offshore) the concentrations from the March 2004 survey were similar to the mean values at all sampling sites.

It is important to note that in no case is there an indication of progressively increasing concentrations of nutrients or other water chemistry constituents over time. Hence, it does not appear that input of materials as a result of leaching of fertilizers is increasing over time.

D. Conservative Mixing Analysis

A useful treatment of water chemistry data for interpreting the extent of material input from land is application of a hydrographic mixing model. In the simplest form, such a model consists of plotting the concentration of a dissolved chemical species as a function of salinity. Comparison of the curves produced by such plots with conservative mixing lines provides an indication of the origin and fate of the material in question (Officer 1979, Dollar and Atkinson 1992, Smith and Atkinson 1993).

Figure 16 shows plots of concentrations of four chemical constituents (Si , NO_3^- , PO_4^{3-} , NH_4^+) as functions of salinity for the samples collected at each site in March 2004. Figures 17 and 18 show the same type of plot with data grouped by site for all past surveys and for the most recent survey. Each graph also shows two conservative mixing lines that are constructed by connecting the end member concentrations of open ocean water with two sources of groundwater: 1) irrigation well No.4 located on the North Course of the Makena Resort and 2) irrigation lake that was fed by irrigation wells 2, 3 and 4. If the parameter in question displays purely conservative behavior (no input or removal from any process other than physical mixing), data points should fall on, or very near, the conservative mixing line. If, however, external material is added to the system through processes such as leaching of fertilizer nutrients to groundwater, data points will fall above the mixing line. If material is being removed from the system by processes such as uptake by biotic metabolic processes, data points will fall below the mixing line.

Dissolved Si represents a check on the model as this material is present in high concentration in groundwater, but is not a major component of fertilizer. In addition, Si is not utilized rapidly within the nearshore environment by biological processes. It can be seen in Figure 16 that when concentrations of Si are plotted as functions of salinity, data points from each of the sampling sites prescribe distinctly different linear arrays. Most of the Si concentrations from Sites 1, 2 and 3 fall below the conservative mixing line created from Well water, but are very close to the mixing line created by the concentration in irrigation lake water. Data points from Site 4 lie slightly above the well water mixing line. Such a pattern suggests that the groundwater mixing with ocean water at the shoreline has slightly different composition between Sites 1, 2, 3 and 4. These differences are likely a result of irrigation of parts of the golf courses with water from the irrigation lakes, as the mixing line created with irrigation lake water has substantially lower slope than the well water mixing line. Even with these subtle differences between sampling locations, it appears that the groundwater endmembers from well No. 4 provides a valid representation of the effects of golf course operation on unaltered groundwater that enters the ocean following flow through the golf courses.

NO_3^- is the form of nitrogen most common in fertilizer mixes that are used for enhancing turf growth. As is the case for Si, there is a wide disparity in the mixing lines created for NO_3^- using well water and irrigation lake water (Figure 16). These differences are likely a result of uptake of NO_3^- by plants in the irrigation lake that results in substantially lower concentrations than in the irrigation well. As with Si, the plots of NO_3^- versus salinity show that data points from each transect lie in a distinct grouping. All of the data points from Sites 1 and 3 lie above all of the mixing lines, indicating a subsidy of NO_3^- to the ocean from sources on land. Such is not the case at Site 2 where all of the concentrations of NO_3^- in the ocean samples are a result of mixing of natural groundwater (i.e., well water) and ocean water. Data points from Site 4, which is considered the control site with no influence from the project exhibits data points close to the well water mixing line. Such a position indicates that the source of groundwater entering the ocean at Site 4 is similar to the groundwater in the irrigation wells above the golf courses. It is clearly evident that there are no subsidies of NO_3^- to the ocean from activities on land at Site 4.

Site 1 is located directly downslope from the boundary between the Makena and Wailea Golf Courses, while Site 3 is located downslope from the area of the South course that is closest to the ocean. It is possible that the apparent subsidy of NO_3^- is a result of leaching of golf course fertilizers to the groundwater lens. In addition to the nearby golf courses, however, there are also newly constructed house lots with landscaping and lawns near the shoreline at Site 1. An old cesspool also remains from a house recently torn down that was directly inshore of Station 3. Thus, it is also possible that the subsidy of NO_3^- in nearshore waters at Sites 1 and 3 may be associated with leaching of sewage nutrients from these residential features as well as leaching of golf course nutrients. Another factor which may lead to increased concentrations of NO_3^- at Site 3 is high levels of fertilization that have occurred on the golf course recently to promote turf growth of the newly planted fairways and greens in the area.

Linear regression of NO_3^- concentrations as a function of salinity for the present survey has a Y-intercept (concentration at a salinity equal to that of well water) of $389 \mu\text{M}$ at Site 1, $149 \mu\text{M}$ at Site 2, $630 \mu\text{M}$ at Site 3, and $109 \mu\text{M}$ at Site 4. Compared to the averaged concentration of NO_3^- measured in four irrigation wells for this survey ($167 \mu\text{M}$), there appears to be a subsidy to groundwater of at least $222 \mu\text{M}$ at Site 1, and $463 \mu\text{M}$ at Site 3. Thus, the concentration of NO_3^- in groundwater entering the ocean at Site 1 and Site 3 is increased by about 130%, and 200%, respectively, compared to the NO_3^- concentration in groundwater that is not affected by leaching from the golf course or other terrestrial sources. These values are nearly identical to the subsidies calculated from the sample concentrations from the survey in February 2003. Hence, these subsidies are not increasing with time. By this analysis, groundwater from Sites 2 and 4 did not show a significant increase in the concentration of NO_3^- compared to naturally occurring groundwater.

Site 1 has also been used as a monitoring station for a similar evaluation of the effects of the Wailea Golf Courses on water chemistry since 1989. The lowest concentrations of NO_3^- relative to salinity at Site 1 occurred during the initial two years of study, with subsequent higher concentrations from 1992 through the last survey in 2001. Hence, there appears to have been an increase of NO_3^- in nearshore waters that was not occurring in 1989-1991. Completion of the Wailea Gold Course occurred in December 1993, while completion of the Makena North Course occurred in November 1993. As the southern region of the Wailea Course and the northern part of the Makena Course overlap in the makai-mauka direction landward of ocean sampling Site 1, it appears likely that the increased concentrations of NO_3^- may be a result of leaching of fertilizer materials from the combined golf courses to groundwater that enters the ocean in the sampling area.

Similarly, the new location of sampling Site 3 is adjacent to the portion of the Makena Course extends to within approximately 50 m of the shoreline. This section of the course was recently grassed with new turf. In order to expedite rapid grow-in of the turn, maximal rates of fertilization are temporarily employed. Such rates of fertilizer application may be the source of the high levels of NO_3^- detected in offshore waters adjacent to the golf course. This site has only been investigated since August 2002 with similar results showing high levels of NO_3^- in

the nearshore zone. Future time-series surveys will reveal if there is a downward trend in NO_3^- concentration with the decrease in fertilizer application on the golf holes adjacent to sampling Site 3.

While there appears to be a long-term, but stable increase in the concentration of NO_3^- in groundwater at Sites 1 and 3, it does not appear that there has been any adverse effect to the biota offshore of this area. Because of the linear relationship of the concentrations of NO_3^- as functions of salinity, there is no indication of uptake of this material in the marine environment. Such lack of uptake indicates that the nutrients are not being removed from the water column by metabolic reactions that could change the composition of the marine environment. Rather, the nutrients entering the ocean through groundwater efflux appear to be dispersed solely by physical mixing processes. As a result, it does not appear that the increased nutrients are causing any alteration in biological community composition or function.

Similar situations have also been observed in other locales in the Hawaiian islands where nutrient subsidies from golf course leaching result in excess NO_3^- in the nearshore zone. At Keauhou Bay on the Big Island, it was shown that owing to the distinct vertical stratification in the nearshore zone, the excess nutrients never come into contact with benthic communities, thereby limiting the potential for increased uptake by benthic algae. In addition, the residence time of the high nutrient water was short enough within the embayment to preclude phytoplankton blooms. As a result, while NO_3^- concentrations doubled as a result of golf course leaching for a period of at least several years, there was no detectable negative effect to the marine environment (Dollar and Atkinson 1992). Owing to the unrestricted nature of circulation and mixing off the Makena project (no confined embayment) it is reasonable to assume that the excess NO_3^- subsidies that are apparent in the present study will not result in alteration to biological communities.

Inspection of the offshore area reveals an apparently healthy coral reef that does not appear to exhibit any negative effects from nutrient loading. There are no areas where excessive algal growth is presently occurring. The averaged concentration of Chl *a* in surface waters within 50 m of the shoreline off of Sites 1 ($0.51 \mu\text{g/L}$) and 3 ($0.41 \mu\text{g/L}$) are lower than at Site 2 ($0.76 \mu\text{g/L}$) and Site 4 ($0.84 \mu\text{g/L}$). In past surveys, Chl *a* at Site 1 has not been higher than any of the other sites and often was less. The lower values of Chl *a* indicate that plankton biomass is not elevated in the areas of highest nutrient input compared to other regions. Continued monitoring will indicate if this trend continues.

It is also important to note that there is no subsidy of NO_3^- at Site 2 (Makena Landing) that was impacted by the flash flood in 1999. While turbidity in this area was affected on a sustained basis (at least for a year following the flood), there is no increase in the form of nitrogen associated with golf course fertilization.

The other form of dissolved inorganic nitrogen, NH_4^+ , does not show a linear pattern of distribution with respect to salinity (Figure 16). Many of the samples with near oceanic salinity

also displayed the highest concentrations of NH_4^+ . The lack of a correlation between salinity and concentration of NH_4^+ suggests that this form of nitrogen is not present in the marine environment as a result of mixing from groundwater sources. Rather, NH_4^+ appears to be generated by natural biotic activity in the ocean waters off Makena. It is also interesting to note that the conservative mixing line for NH_4^+ constructed from the endpoint concentration from irrigation lake 10, composed of well water and sewage effluent, has a substantially steeper slope than the mixing line constructed from water from irrigation Well 4.

PO_4^{3-} is also a major component of fertilizer, but is usually not found to leach to groundwater to the extent of NO_3^- , owing to a high absorptive affinity of phosphorus in soils. Data points for PO_4^{3-} from Site 1 fall on the well water mixing line, while data points from all the other sites fall above both lines (Figure 16). This is in contrast to NO_3^- , where data points from Sites 1 and 3 fell above the mixing line. The lack of consistency between the patterns of NO_3^- and PO_4^{3-} at Site 1 suggests that there are different processes affecting the relative subsidies of PO_4^{3-} and NO_3^- at the different survey sites. The elevated NO_3^- at Site 1, which is influenced by golf course and residential landscaping, is not reflected in similar subsidies of PO_4^{3-} . At Sites 2, 3 and 4 there is an apparent subsidy of PO_4^{3-} relative to natural groundwater.

E. Compliance with DOH Standards

Tables 1 and 2 also show samples that exceed DOH water quality standards for open coastal waters under "wet" and "dry" conditions. These criteria are applied depending upon whether the area is likely to receive less than (dry) or greater than (wet) 3 million gallons of groundwater input per mile per day. As it is impossible to accurately estimate groundwater and surface water discharge, both wet and dry standards are considered. DOH standards include specific criteria for three situations; criteria that are not to be exceeded during either 10% or 2% of the time, and criteria that are not to be exceeded by the geometric mean of samples. With only thirteen samples collected to date from each sampling station, comparison of the 10% or 2% of the time criteria for any sample is not statistically meaningful. However, comparing sample concentrations to these criteria provide an indication of whether water quality is near the stated specific criteria.

Boxed values in Tables 1 and 2 show instances where measurements exceed the DOH standards under dry conditions, while boxed and shaded values show instances where measurements exceed DOH standards under wet conditions. Twenty-five samples collected in the March 2004 survey exceeded the 10% criteria for NO_3^- under both dry and wet conditions, (Table 1). From the preceding discussion of conservative mixing, it is apparent that natural input of groundwater to the nearshore zone can substantially raise the concentrations of NO_3^- . While there is no statistically significant increase of NO_3^- over natural groundwater input at Sites 2 and 4, samples from both these areas exceed the DOH limits. This is especially important at Control Site 4, where there is no influence from the golf courses. Thus, it appears that input of natural groundwater can result in ocean water quality measurements that can be interpreted to exceed DOH standards.

In addition, results from the March 2004 survey indicated that nine measurements of NH_4^+ and TN, one measurement of turbidity and twelve measurements of Chl *a* exceeded the 10% DOH criteria under dry conditions. No measurements of TP exceeded the 10% dry standards during March 2004. When compared under wet conditions, only one measurement of NH_4^+ , seven measurements of TN and three measurements of Chl *a* were exceeded. Tables 3 and 4 show geometric means of samples collected at the same locations during the thirteen increments of the monitoring program at all four sites. Also shown in these tables are the samples that exceed the DOH geometric mean limits for open coastal waters under dry (boxed) and wet (boxed and shaded) conditions. For NO_3^- , NH_4^+ , TN numerous dry and wet standards were exceeded. All but four samples exceeded the standards for Chl *a* and eighteen cases of turbidity exceeded the dry standards (three cases exceed the wet standards). Site 4 is considered a control transect, in that it is not located offshore of a golf course. However, it can be seen in Tables 3-4 that the number of samples that exceed geometric mean criteria at Site 4 are comparable to the other three sites, all of which are located downslope from the Makena courses. Hence, it appears that the golf courses cannot be attributed as the sole (or even major) factor causing water quality to exceed geometric mean standards.

IV. SUMMARY

- The thirteenth phase of water chemistry monitoring of the nearshore ocean off the Makena Golf Course was carried out on March 6, 2004. Fifty ocean water samples were collected on three transects spaced along the project ocean frontage. One transect was located outside of the project area in order to serve as a control site. Site 1 was located at the northern boundary of the project, Site 2 was located near the central part of the North Golf Course near Makena Landing, Site 3 was downslope from the part of South course that comes closest to the shoreline, and Control Site 4 was located to the south of Makena Resort off the 'Ahihi-Kina'u Natural Area Reserve.
- Transects extended from the shoreline out to the open coastal ocean. Water samples were analyzed for chemical criteria specified by DOH water quality standards, as well as several additional criteria. In addition, water samples were collected from seven irrigation wells located on the Makena Golf Courses. Six 18" suction lysimeters placed around the courses were installed to collect irrigation water that percolates through the turf layer. Two of these lysimeters yielded water during March 2004.
- Water chemistry constituents that occur in high concentration in groundwater (Si , NO_3^- and PO_4^{3-}) displayed distinct horizontal gradients with high concentrations nearest to shore and decreasing concentrations moving seaward. Based on salinity, groundwater input was greatest at Sites 1 and 4, but was clearly evident at all four sampling sites. As Site 4 was not located in the vicinity of any golf course, it is apparent that groundwater input is not solely dependent on land usage.

- Vertical stratification of the water column was evident beyond 10 m of the shoreline at Sites 1 and 4, but not at the other two sites during the current survey. Vertical and horizontal patterns of distribution indicate that physical mixing processes generated by wind, waves and currents were not sufficient for complete mixing of the water column at these sites.
- Turbidity and Chl *a* were elevated at the shoreline at all four sites as has been the case in all previous surveys. Site 2 is located at the point where sediment-laden storm water runoff entered the ocean following a flash flood in October 1999. While the highly turbid conditions associated with the runoff event are no longer evident, normal processes of circulation (tidal exchange, wave mixing) and the sand/mud bottom result in slightly more turbid conditions at Makena Landing (Site 2) compared to the other sampling areas.
- Most water chemistry constituents that do not occur in high concentrations in groundwater did not display any recognizable horizontal or vertical trends.
- Scaling nutrient concentrations to salinity indicates that there were significant subsidies of NO_3^- to the nearshore ocean at Sites 1 and Site 3. The subsidy substantially increases the concentration of NO_3^- in groundwater flowing to the ocean compared to natural groundwater. The area shoreward of Site 1 includes an overlap of the southern part of the Wailea Gold Course and the northern part of the Makena North Course, as well as residential development. Site 3 is directly downslope from the South Course in an area that was recently planted with new turf, which requires maximal fertilization to expedite growth. In addition, a cesspool remains from a house that was recently torn down lies directly inshore from Site 3. Hence, the subsidies of NO_3^- noted at Sites 1 and 3 may result from a combination of sources. Similar subsidies of NO_3^- were not evident at Site 2, off the Makena North Course (Makena Landing) or at Site 4, located beyond the influence of the golf course. Thus, other sources besides golf course fertilizers may be contributing to the nutrient subsidies. If the subsidy of NO_3^- is a result of construction and operation of the existing golf courses, future monitoring surveys should indicate if the leaching of NO_3^- to the ocean is a temporary phenomenon that decreases with time, or is a continuing pattern.
- There is no subsidy of PO_4^{3-} corresponding to the subsidy of NO_3^- at Site 1. However, there does appear to be subsidies of PO_4^{3-} at Sites 3 and 4. As Site 4 is not located off the golf course, increased concentrations of PO_4^{3-} are originating for alternate sources.
- Comparing water chemistry parameters to DOH standards revealed that numerous measurements of NO_3^- , a few measurements of NH_4^+ , TN, and several measurements of Chl *a* exceeded the DOH "not to exceed more than 10% of the time" criteria for dry and wet conditions of open coastal waters. No measurements of TP and only one measurement of turbidity exceeded these standards in March 2004. It is apparent that the concentrations of NO_3^- in nearshore marine waters that contains a mixture of

seawater and natural groundwater may exceed DOH criteria with no subsidies from human activities on land. Numerous values of NO_3^- , NH_4^+ , TP, TN, turbidity and Chl *a* exceeded specified limits for geometric means. Such exceedances occurred at all survey sites, including the control site that was far from any golf course influence.

- As in past surveys, there appears to be a definite input of fertilizer nutrients (particularly NO_3^-) to the nearshore ocean at sampling sites downslope from parts of the Makena Golf Courses. However, this input does not appear to be increasing from previous surveys, and does not appear to be detrimental to marine community structure.
- The next phase of the Makena Golf Course monitoring program is scheduled for summer of 2004.

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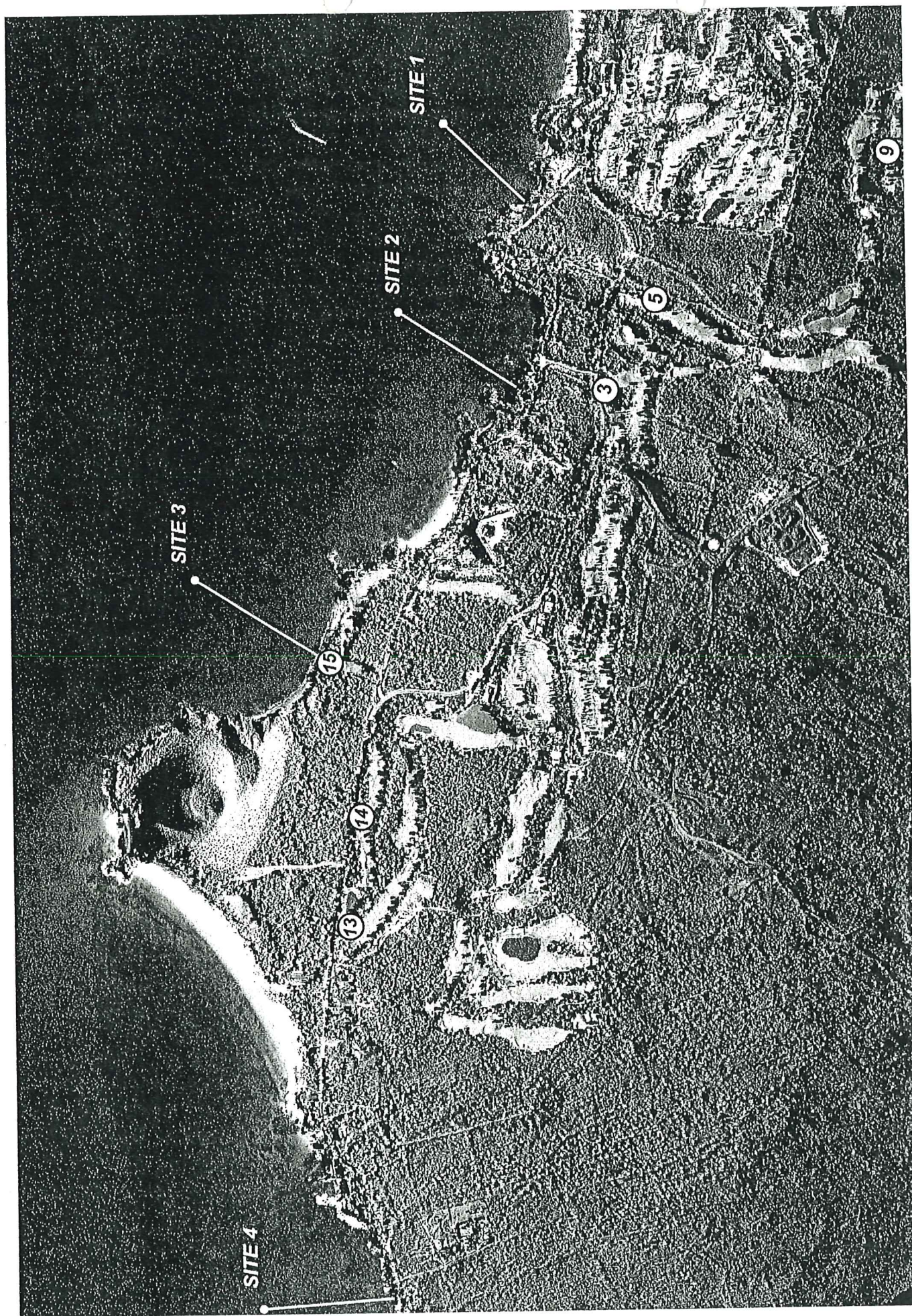


FIGURE 1. Aerial photograph of Makena Golf Courses on Southwest coastline of Maui showing locations of four ocean water sampling sites. White circles outlined in red show locations of six suction lysimeters that are installed on golf course. Numbers in circles indicate lysimeter locations by golf hole.

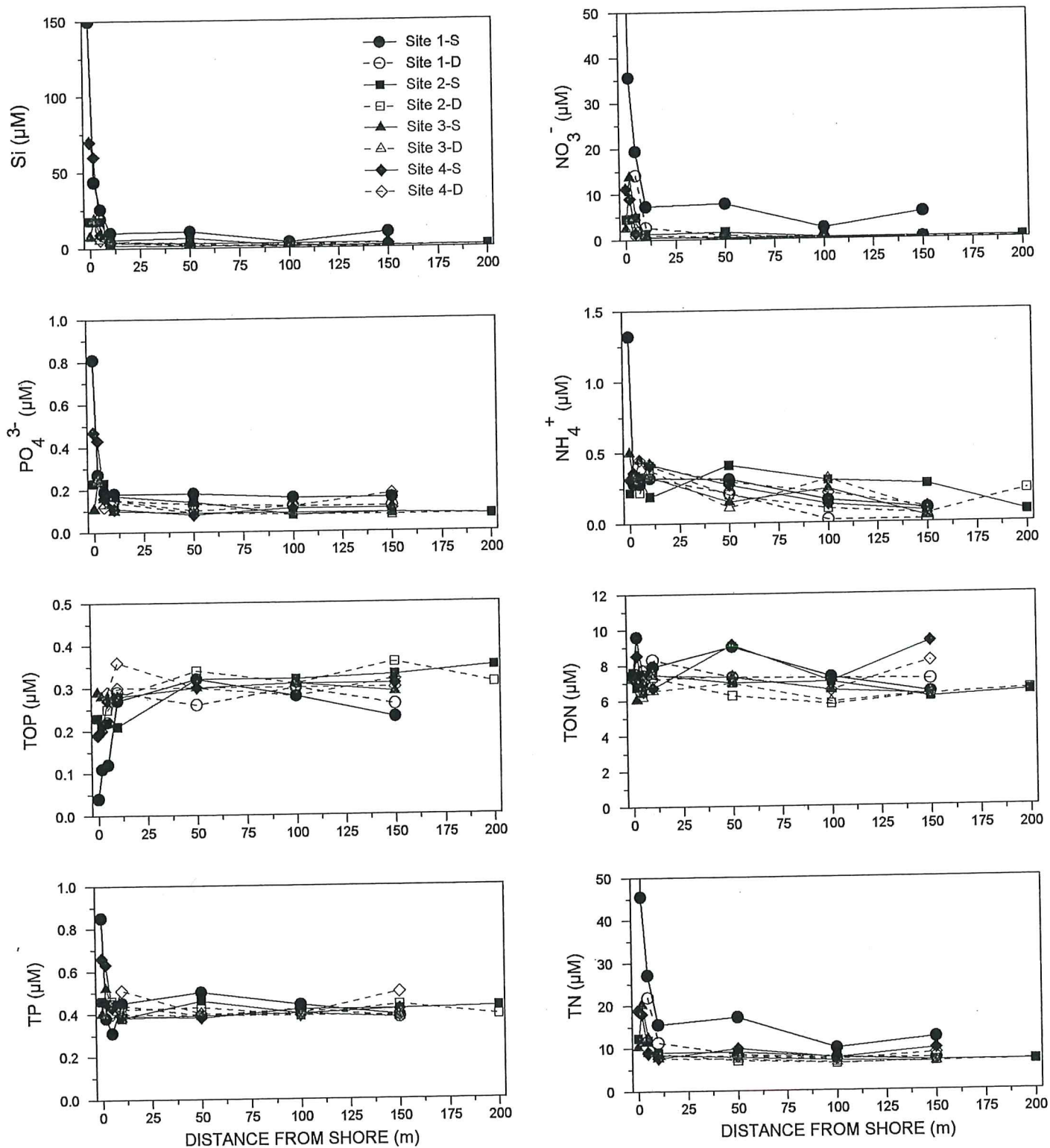


FIGURE 2. Plots of dissolved nutrients in surface (S) and deep (D) samples collected on March 6, 2004 as a function of distance from the shoreline in the vicinity of Makena Golf Course. For site locations, see Figure 1.

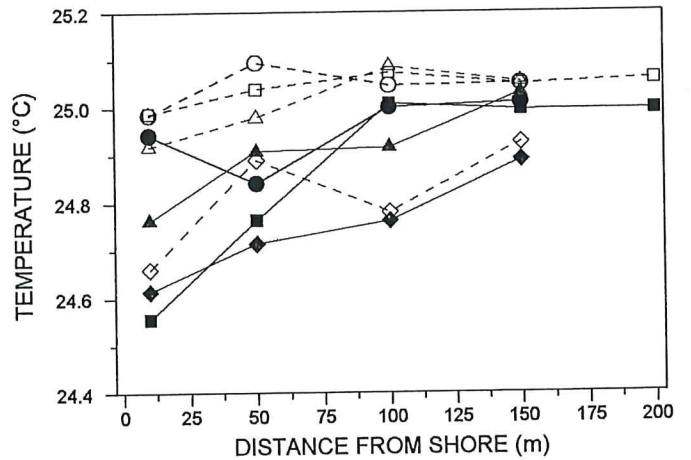
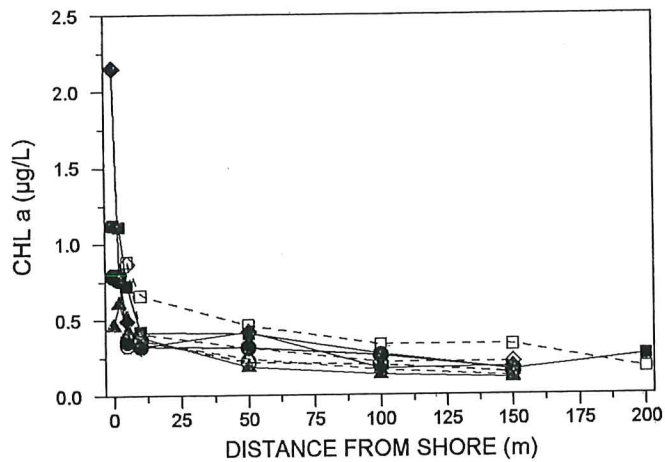
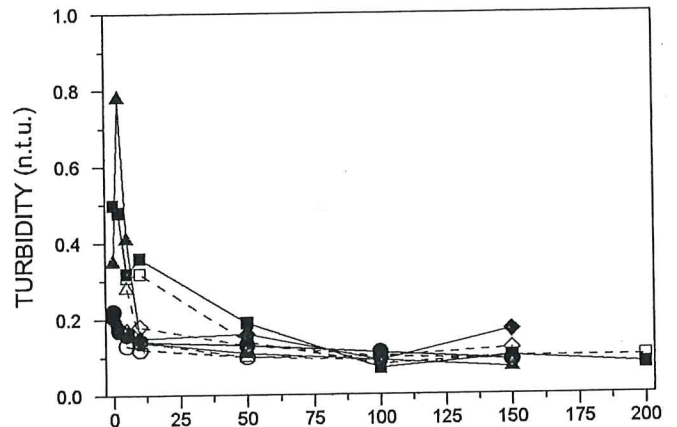
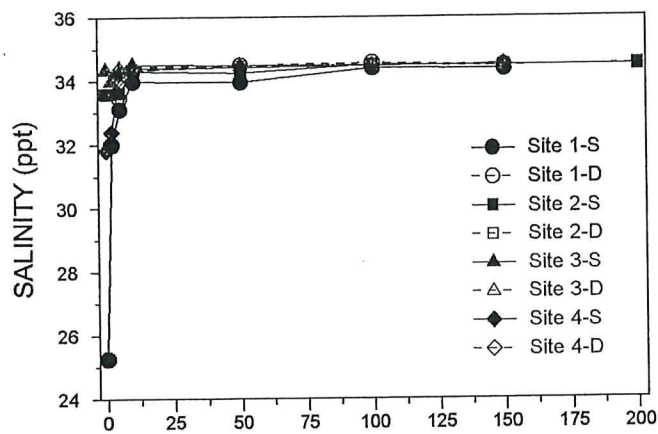


FIGURE 3. Plots of water chemistry constituents in surface (S) and deep (D) samples collected on March 6, 2004 as a function of distance from the shoreline in the vicinity of Makena Golf Course. For site locations, see Figure 1.

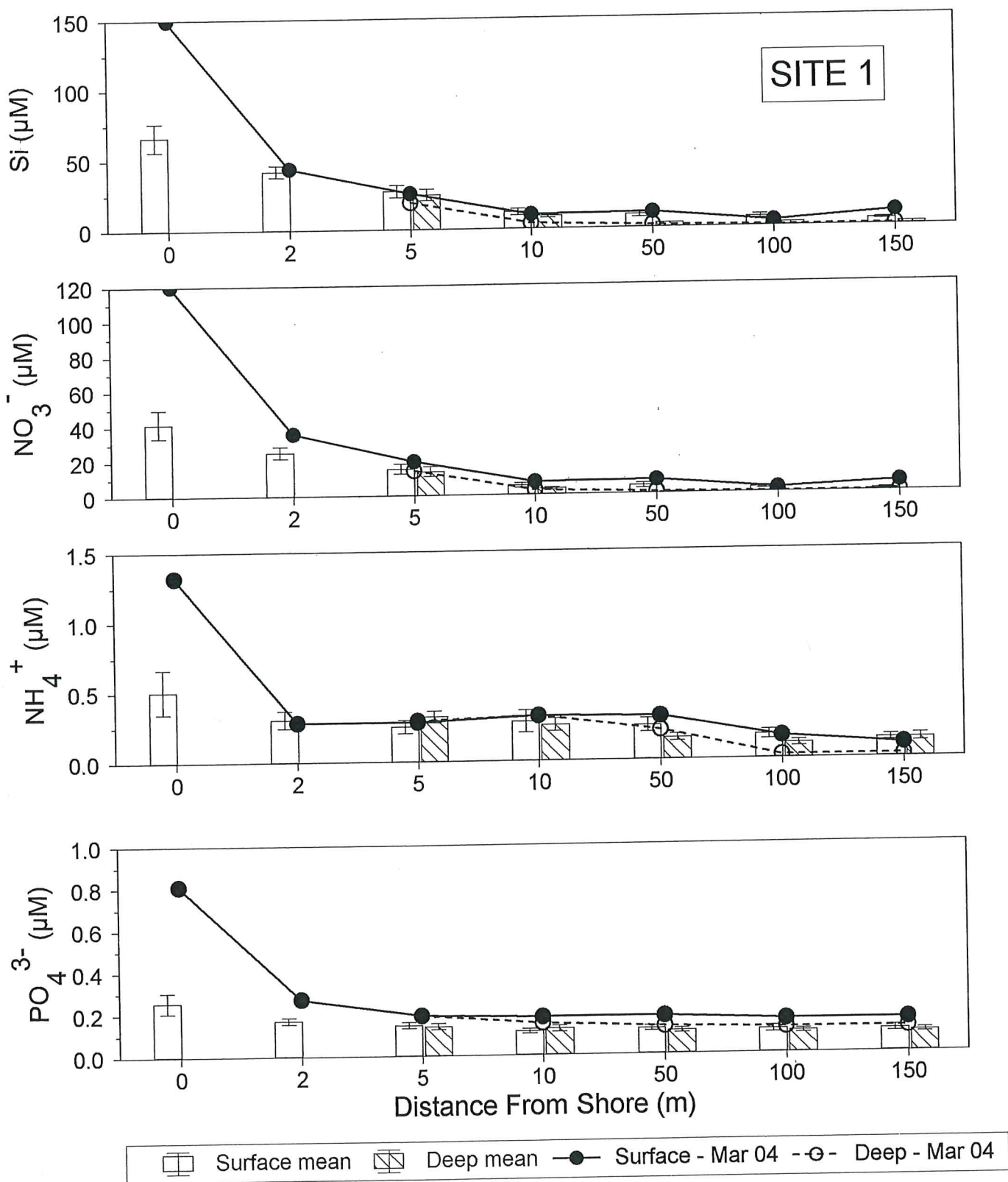


FIGURE 4. Plots of dissolved nutrient constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 1, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey, bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

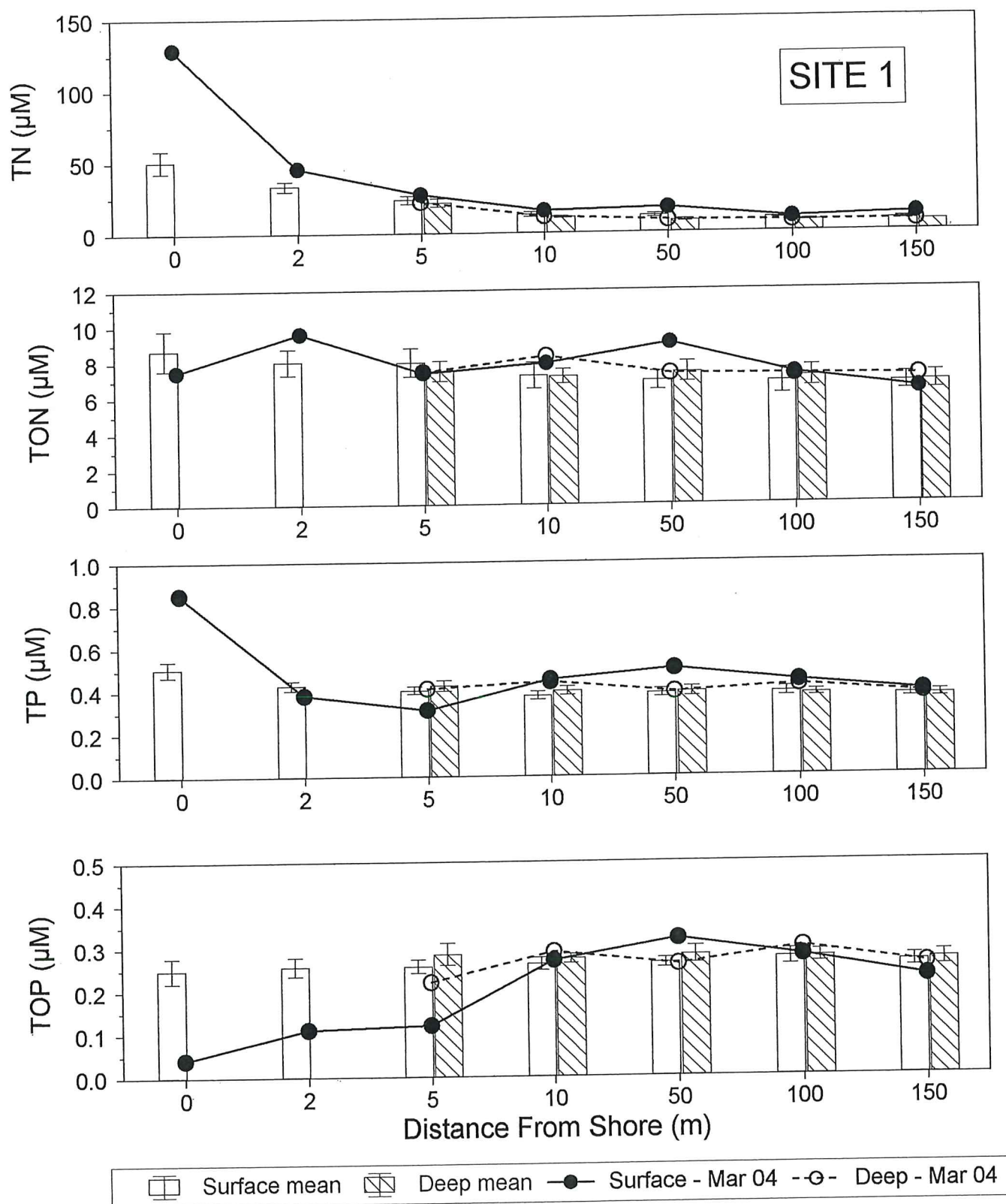


FIGURE 5. Plots of dissolved nutrient constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 1, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey, bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

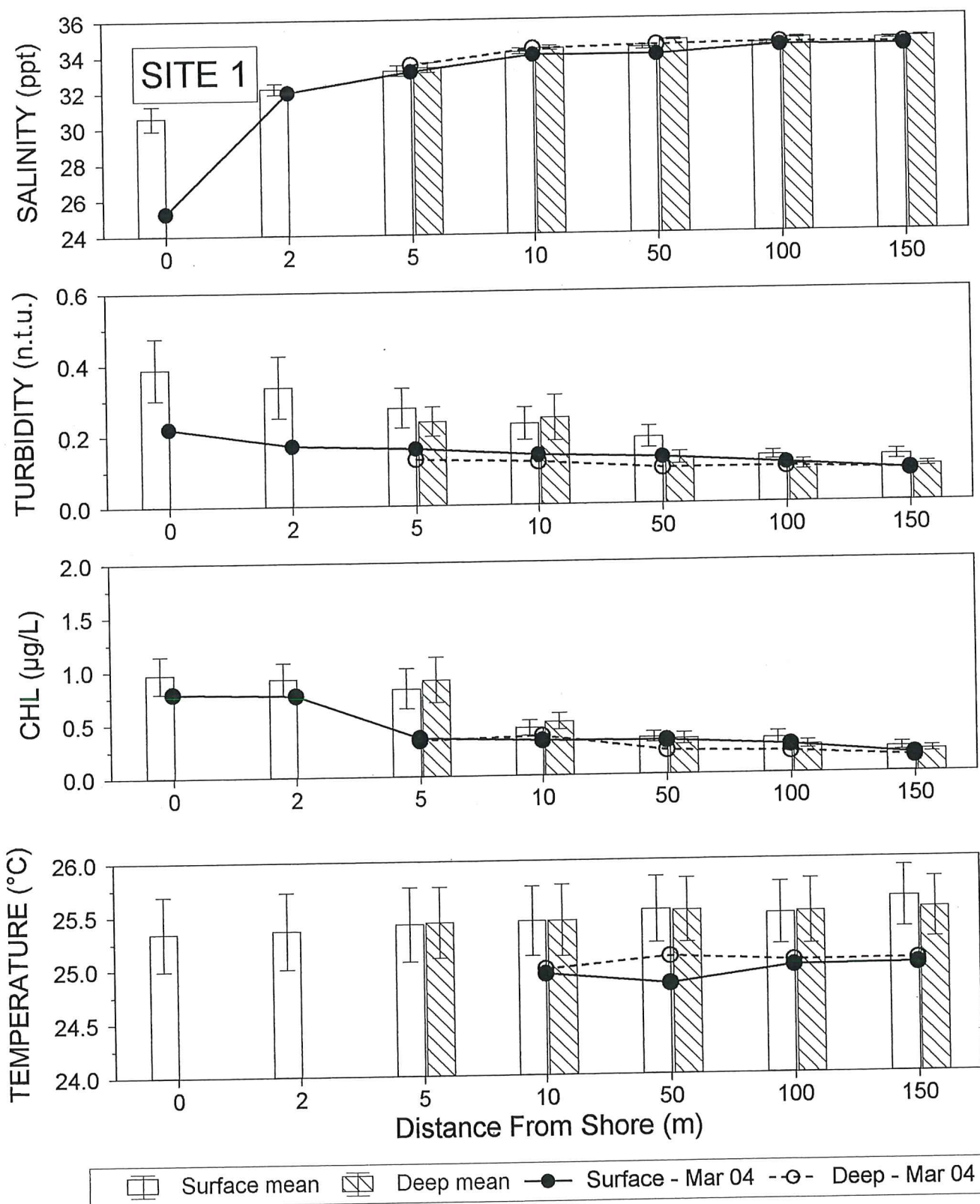


FIGURE 6. Plots of water chemistry constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 1, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey (temperature data near shoreline unavailable), bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

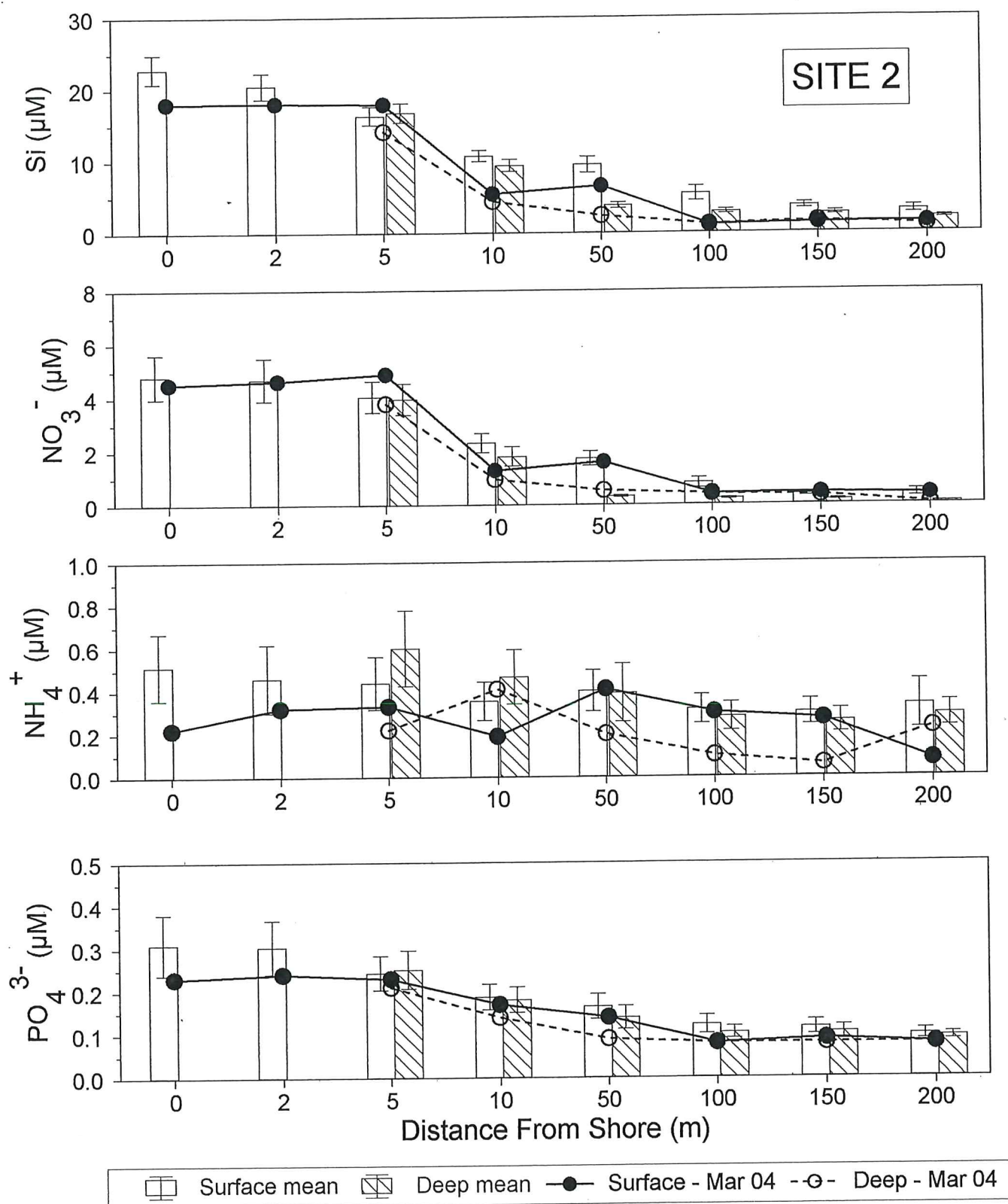


FIGURE 7. Plots of dissolved nutrient constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 2, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey, bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

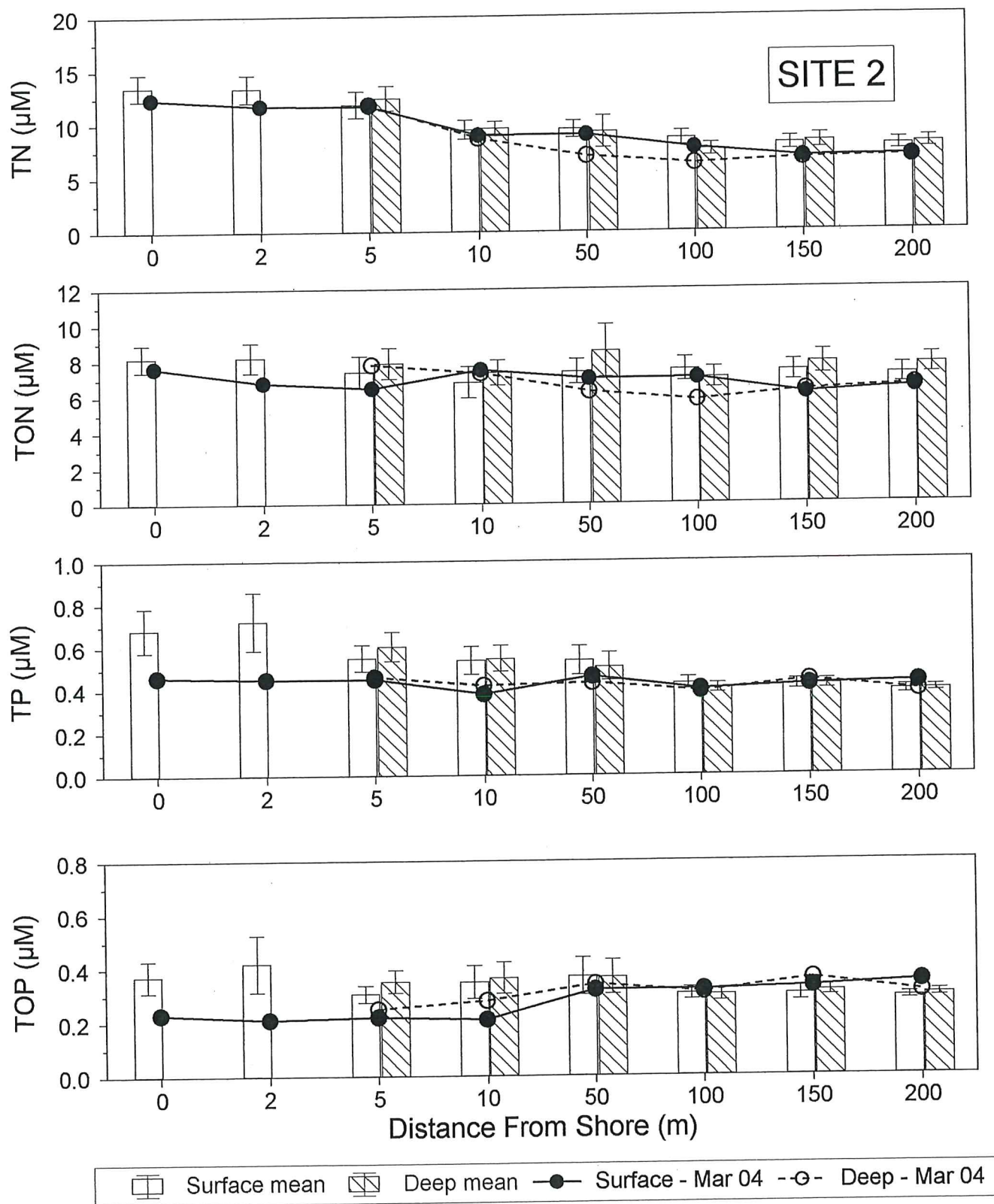


FIGURE 8. Plots of dissolved nutrient constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 2, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey, bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

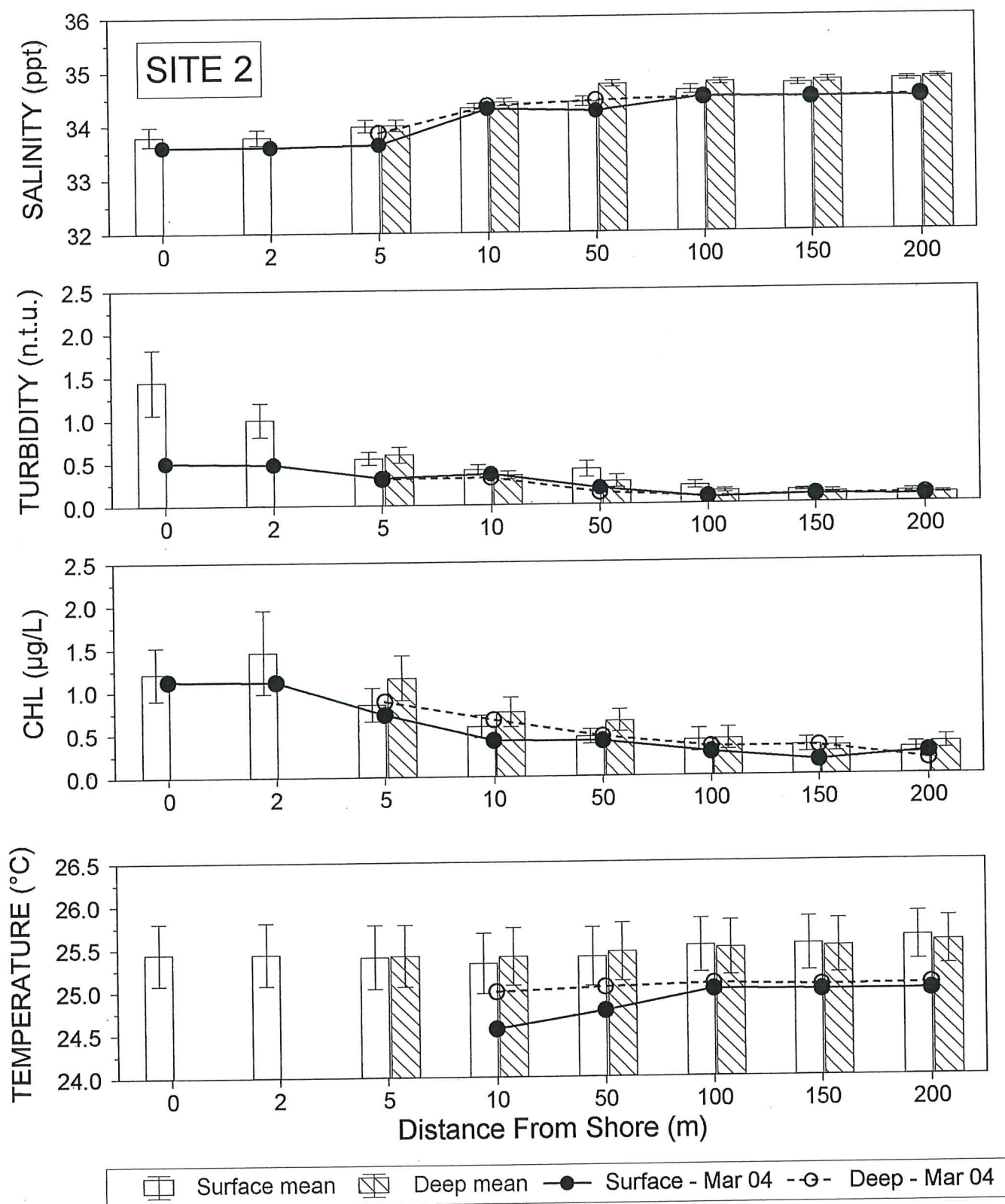


FIGURE 9. Plots of water chemistry constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 2, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey (temperature data near shoreline unavailable), bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

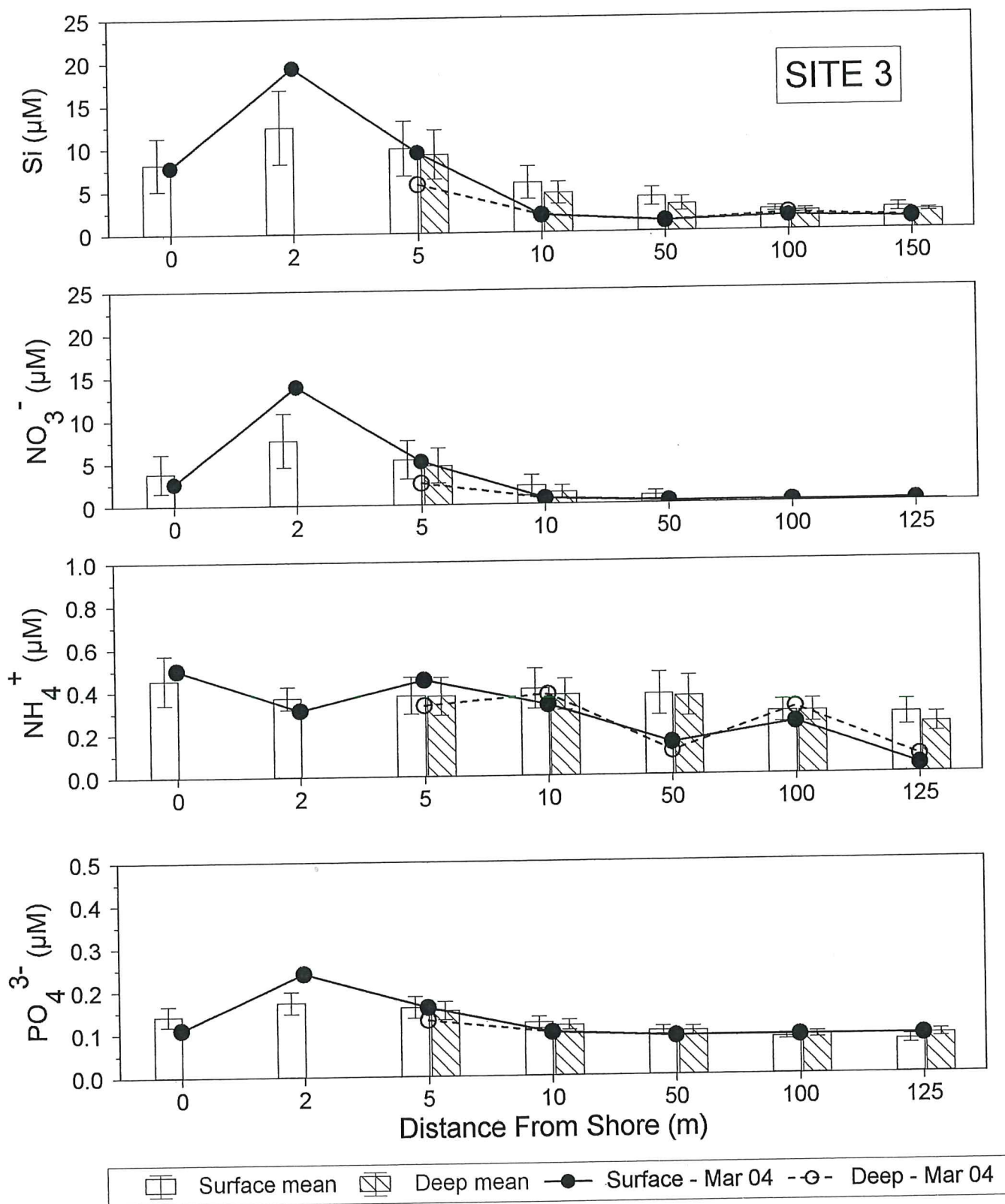


FIGURE 10. Plots of dissolved nutrient constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 3, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey, bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

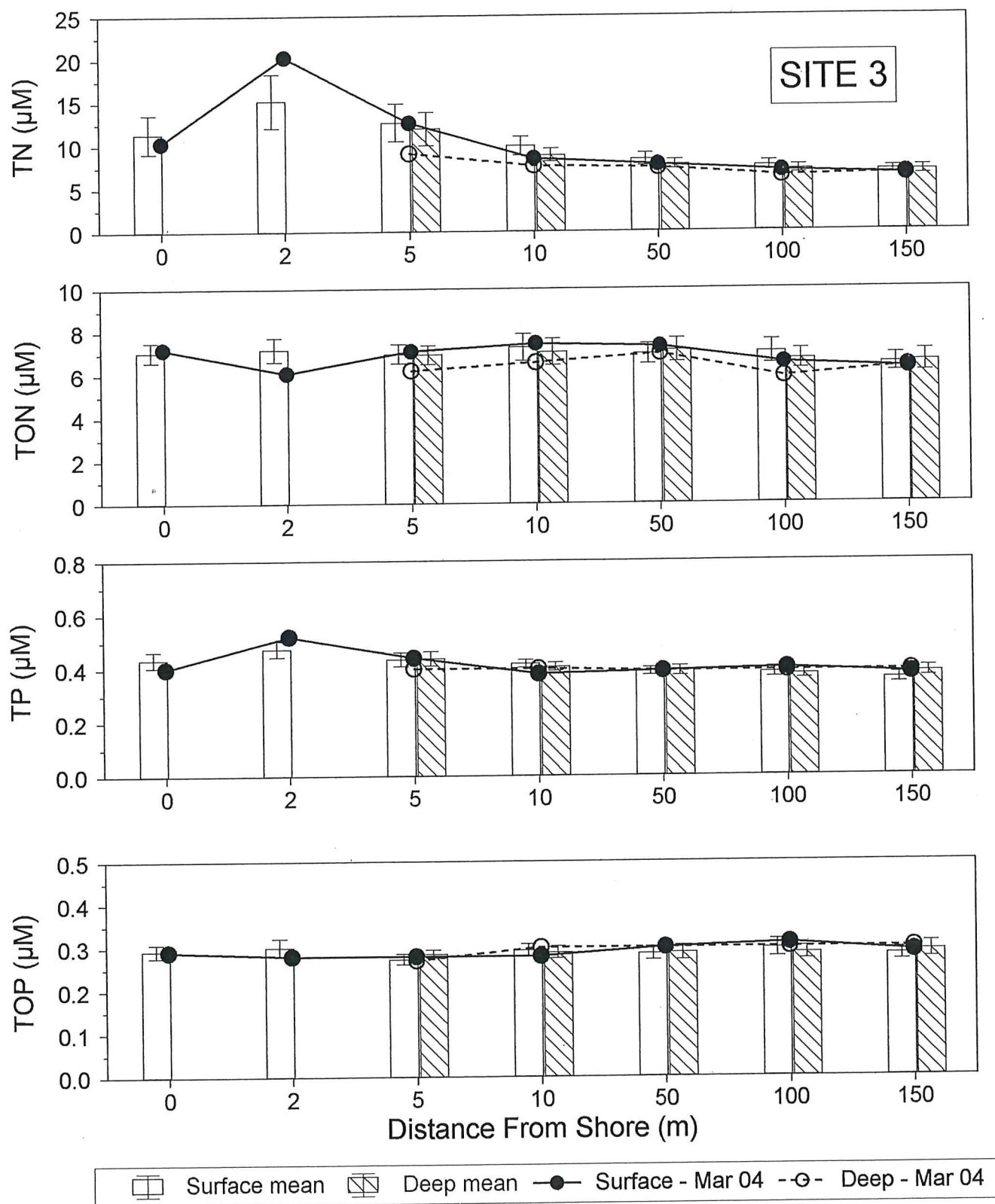


FIGURE 11. Plots of dissolved nutrient constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 3, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey, bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

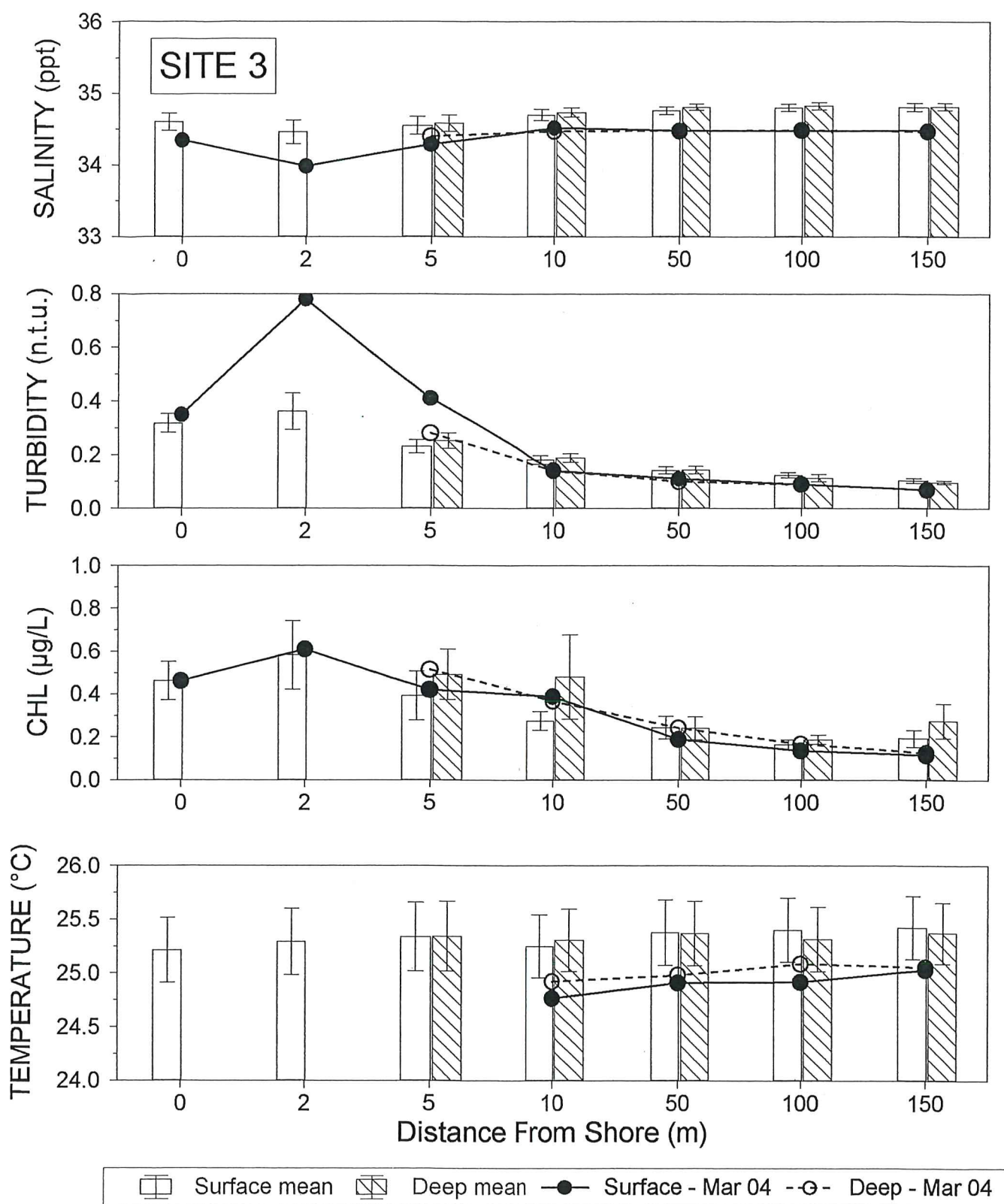


FIGURE 12. Plots of water chemistry constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 3, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey (temperature data near shoreline unavailable), bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

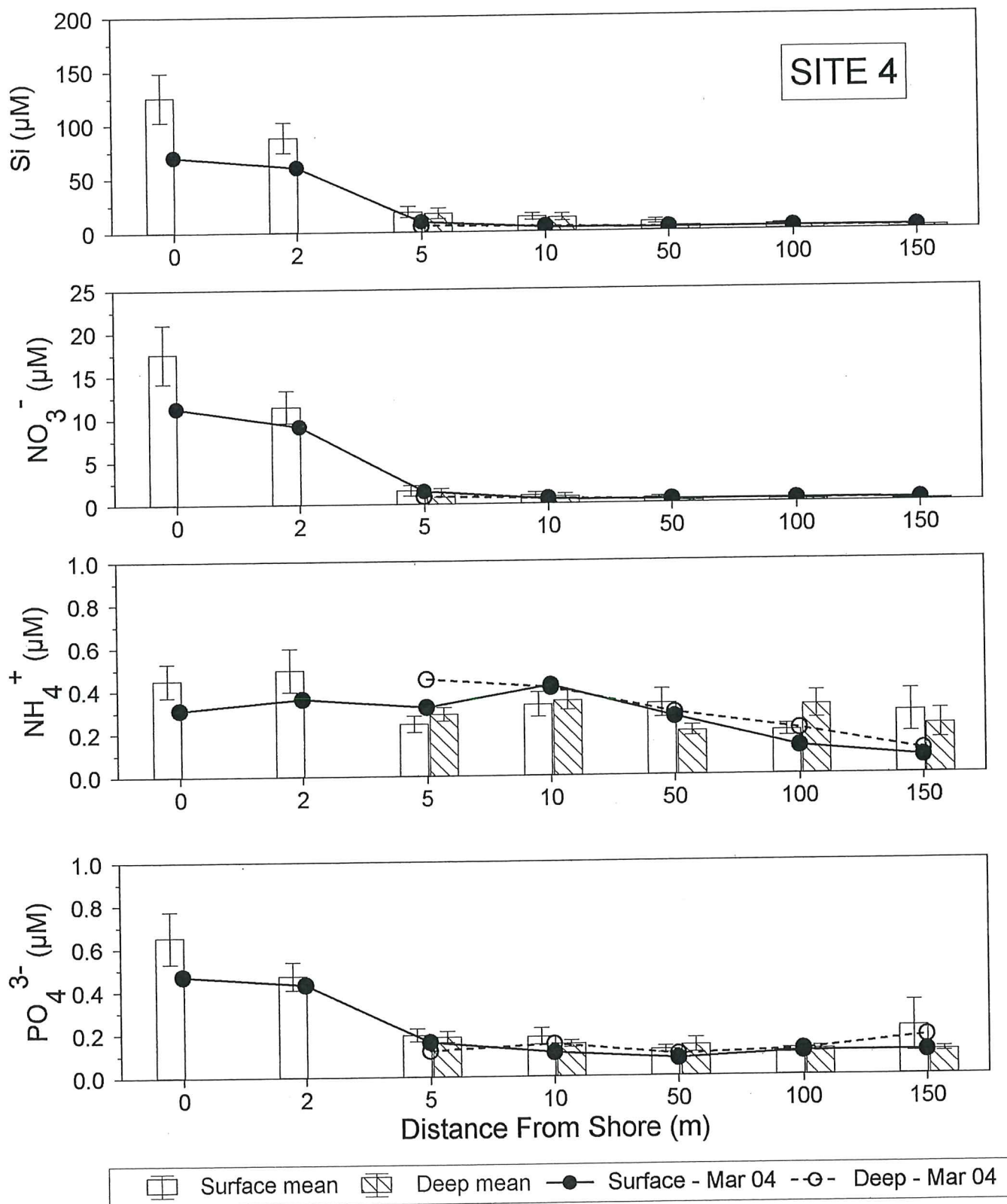


FIGURE 13. Plots of dissolved nutrient constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 4, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey, bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. Note Y-axis scale break for Si and NO_3^- . For site location, see Figure 1.

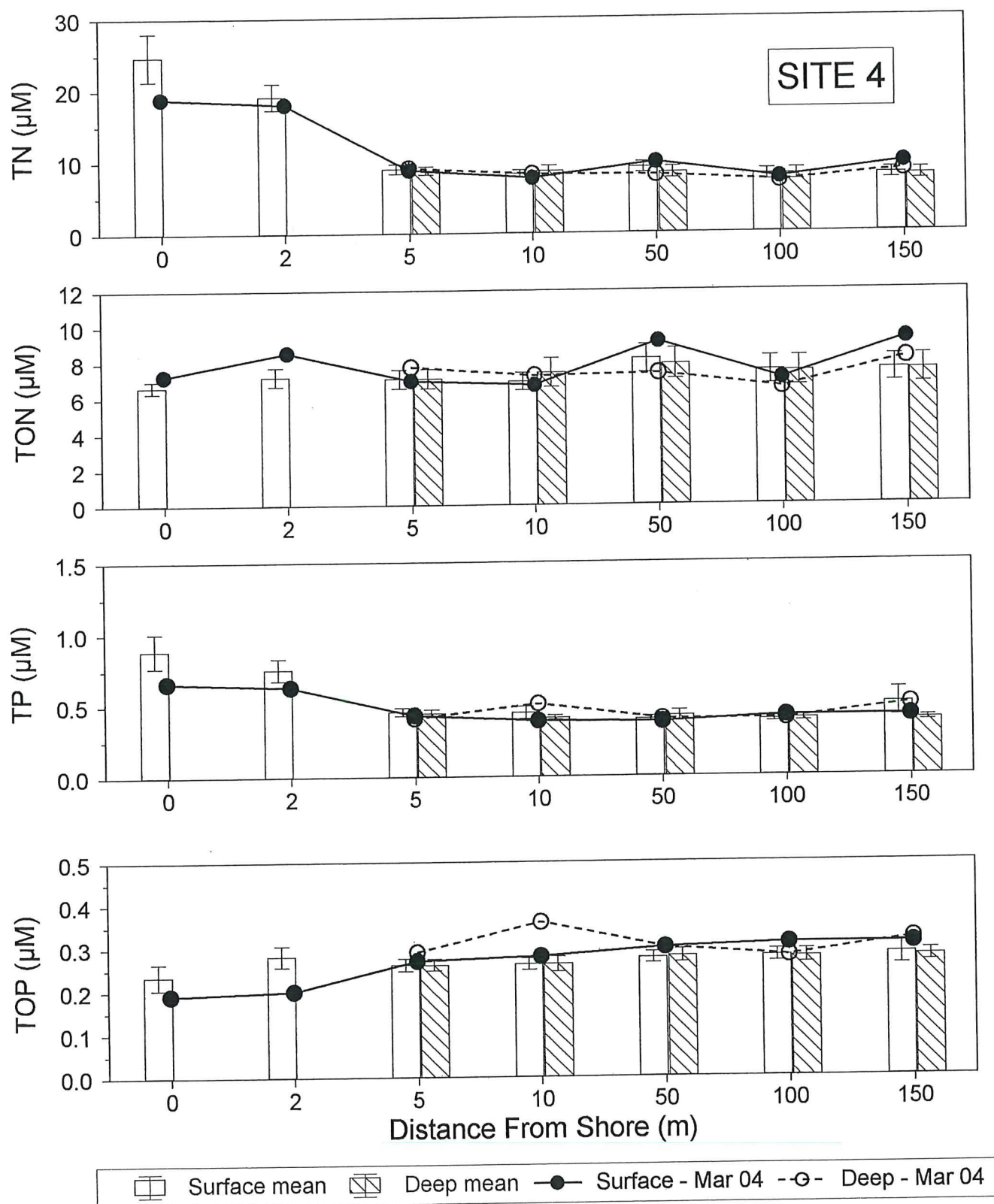


FIGURE 14. Plots of dissolved nutrient constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 4, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey, bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

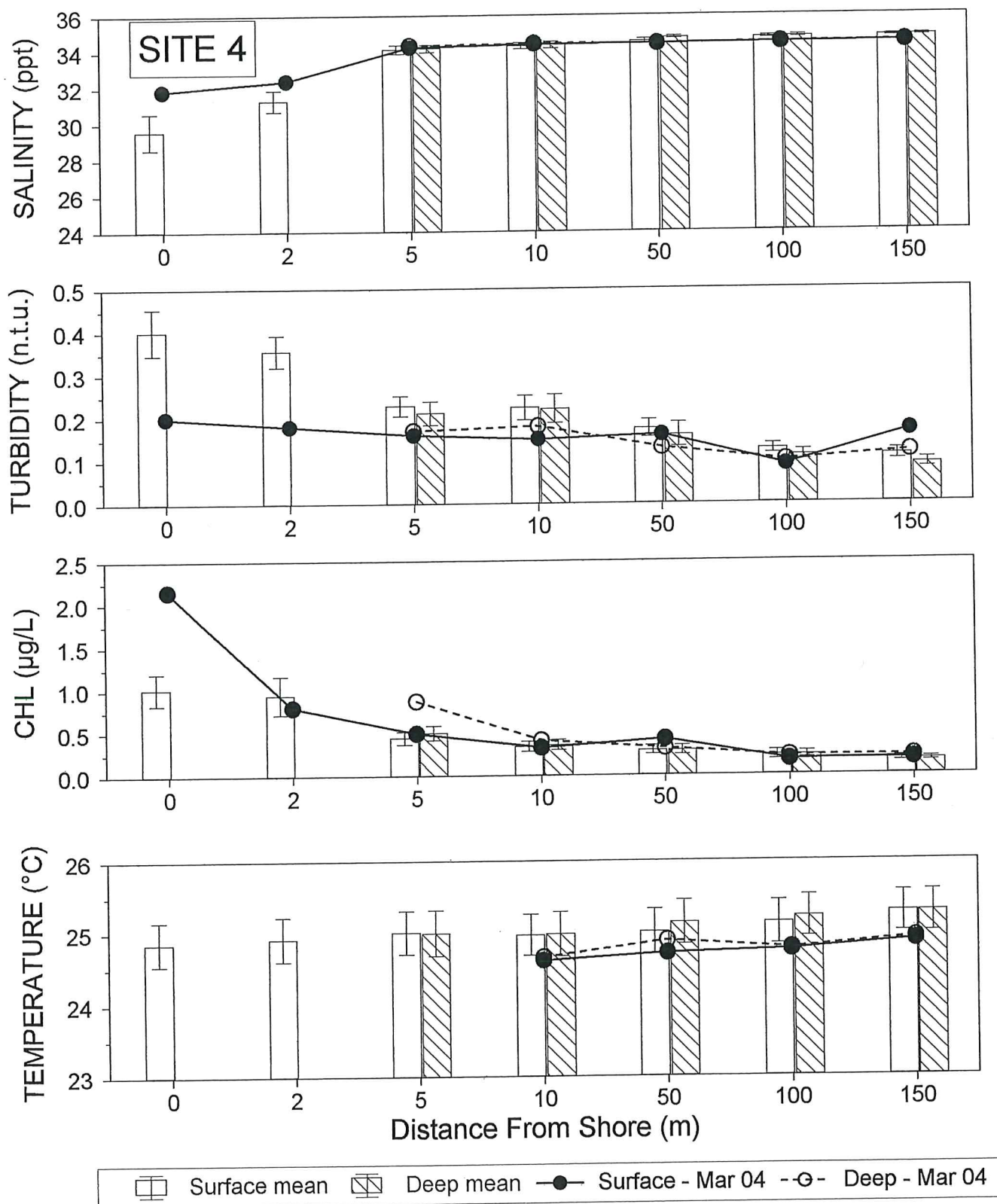


FIGURE 15. Plots of water chemistry constituents measured in surface and deep water samples as a function of distance from the shoreline at Site 4, offshore of the Makena Golf Course. Data points and connected lines from samples collected during the most recent survey (temperature data near shoreline unavailable), bar graphs represent mean values at each sampling station for surveys conducted since August 1995 (N=13). Error bars represent standard error of the mean. For site location, see Figure 1.

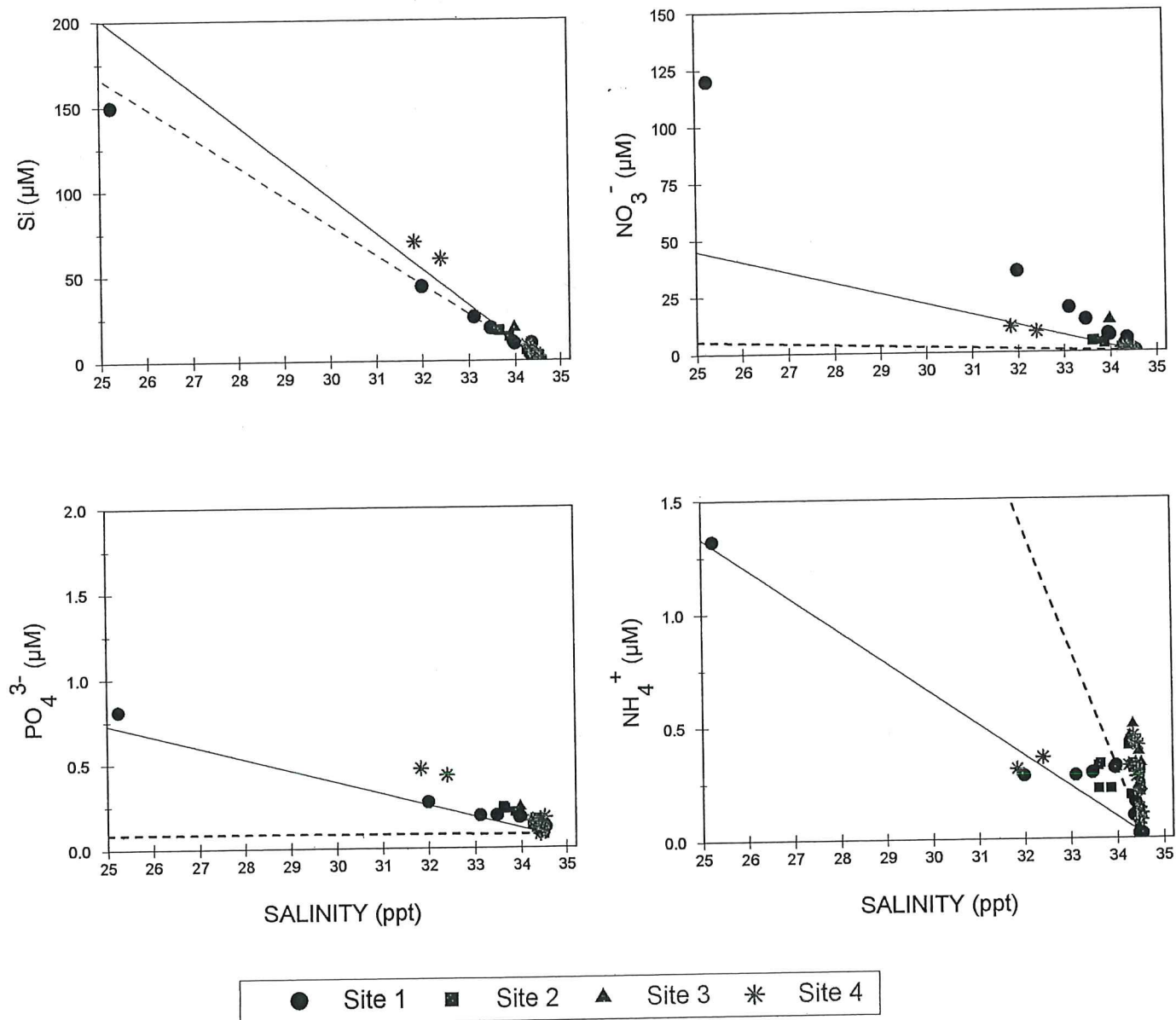
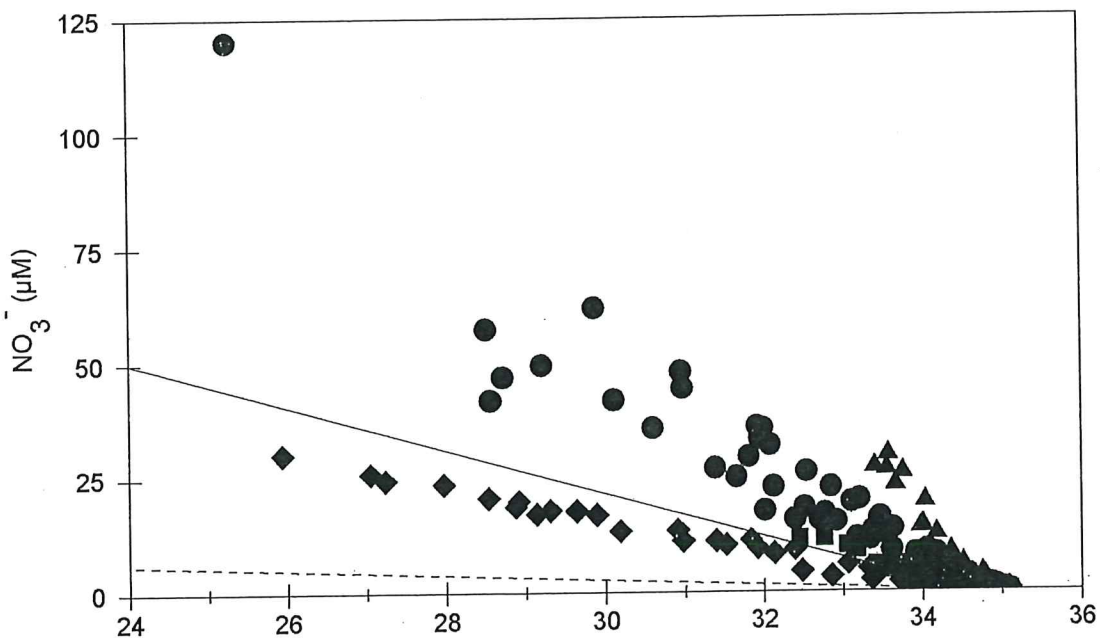
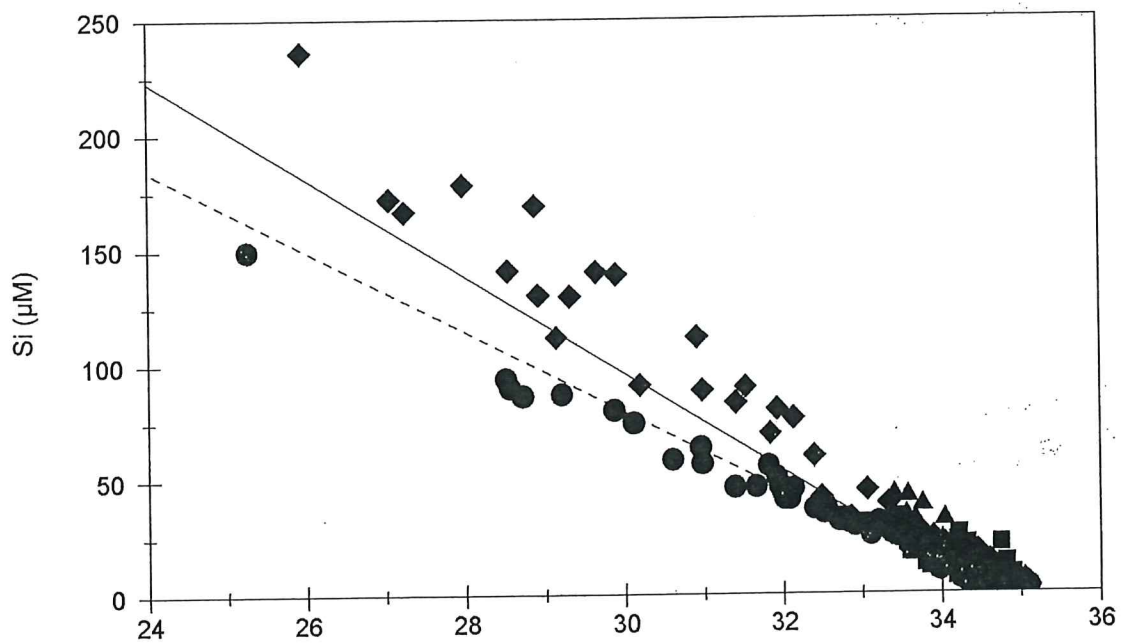


FIGURE 16. Mixing diagram showing concentration of dissolved nutrients from samples collected offshore of the Makena Golf Course on March 6, 2004 as functions of salinity. Solid red line in each plot is conservative mixing line constructed by connecting the concentrations in open coastal water with water from a golf course irrigation well. Dotted black line is mixing line constructed from open coastal water with water from irrigation lake 10 used to feed both North and South courses. For sampling site locations, see Figure 1.



● Site 1 ■ Site 2 ▲ Site 3 ◆ Site 4 ● Mar 04 Site 1 ■ Mar 04 Site 2 ▲ Mar 04 Site 3 ◆ Mar 04 Site 4

FIGURE 17. Silicate and nitrate, plotted as a function of salinity for surface samples collected since August 1995 at four sites offshore of the Makena Golf Course. Black symbols represent combined data from surveys conducted between August 1995 and March 2004. Red symbols are data from current survey. Solid red line in each plot is conservative mixing line constructed by connecting the concentrations in open coastal water with water from a golf course irrigation well. Dotted black line is mixing line constructed from open coastal water with water from irrigation lake 10 used to feed both North and South courses. For sampling site locations, see Figure 1.

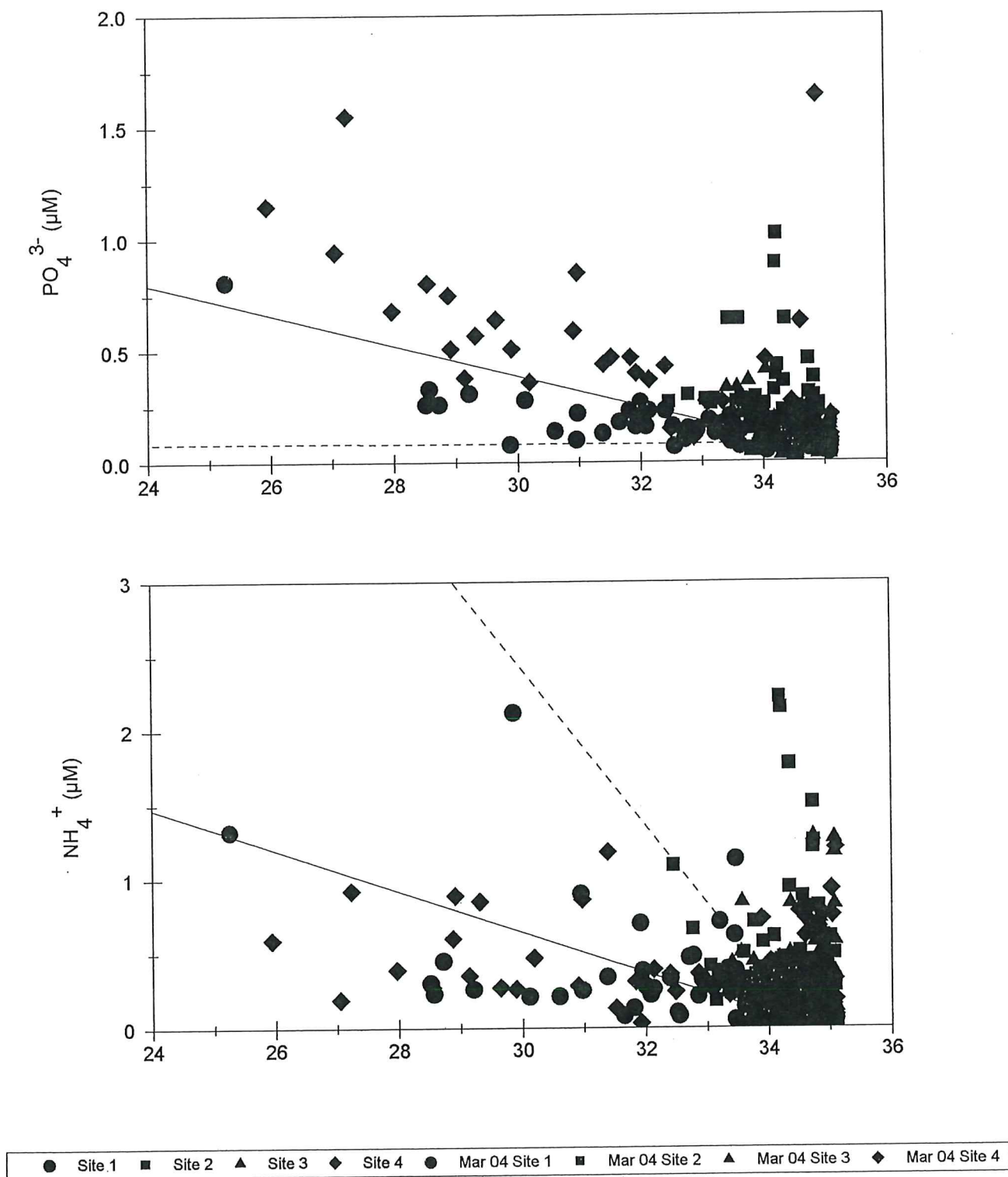


FIGURE 18. Phosphate and ammonium, plotted as a function of salinity for surface samples collected since August 1995 at four sites offshore of the Makena Golf Course. Black symbols represent combined data from surveys conducted between August 1995 and March 2004. Red symbols are data from current survey. Solid red line in each plot is conservative mixing line constructed by connecting the concentrations in open coastal water with water from a golf course irrigation well. Dotted black line is mixing line constructed from open coastal water with water from irrigation lake 10 used to feed both North and South courses. For sampling site locations, see Figure 1.

TABLE 1. Water chemistry measurements from ocean water samples collected in the vicinity of the Makena Golf Course on March 6, 2004. Nutrient concentrations are shown in micromolar units (μM). Abbreviations as follows: DFS=distance from shore; S=surface; D=deep, BDL=below detection limit, NA=data not available. Also shown are the State of Hawaii, Department of Health (DOH) "not to exceed more than 10% of the time" and "not to exceed more than 2% of the time" water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH 10% "dry" standards; boxed and shaded values exceed DOH 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT	DFS (m)	DEPTH (m)	PO4 (μM)	NO3 (μM)	NH4 (μM)	Si (μM)	TOP (μM)	TON (μM)	TP (μM)	TN (μM)	TURB (NTU)	SALINITY (‰)	CHL a ($\mu\text{g/L}$)	TEMP (deg.C)	pH (std. units)	O2 % Sat
MAKENA 1	0 S	1	0.81	120.05	1.32	149.53	0.04	7.47	0.85	128.84	0.22	25.259	0.79	NA	7.93	NA
	2 S	1	0.27	35.64	0.28	43.66	0.11	9.59	0.38	45.51	0.17	31.990	0.77	NA	8.05	NA
	5 S	1	0.19	19.44	0.28	25.57	0.12	7.38	0.31	27.10	0.16	33.109	0.36	NA	8.06	NA
	5 D	2.5	0.19	14.16	0.29	19.17	0.22	7.43	0.41	21.88	0.13	33.465	0.34	NA	8.06	NA
	10 S	1	0.18	7.29	0.32	9.98	0.27	7.90	0.45	15.51	0.14	33.979	0.33	24.9	8.05	100.2
	10 D	3	0.15	2.67	0.32	3.74	0.29	8.30	0.44	11.29	0.12	34.322	0.37	25.0	8.05	93.2
	50 S	1	0.18	7.80	0.31	10.82	0.32	9.02	0.50	17.13	0.13	33.948	0.31	24.8	8.04	96.4
	50 D	4.5	0.13	0.90	0.21	1.57	0.26	7.29	0.39	8.40	0.10	34.482	0.22	25.1	8.02	99.6
	100 S	1	0.16	2.44	0.16	3.67	0.28	7.29	0.44	9.89	0.11	34.385	0.26	25.0	8.06	97.7
	100 D	10	0.12	0.23	BDL	0.66	0.30	7.22	0.42	7.45	0.10	34.542	0.20	25.0	8.11	98.2
	150 S	1	0.16	5.81	0.10	10.06	0.23	6.42	0.39	12.33	0.09	34.358	0.17	25.0	8.06	99.0
	150 D	15	0.12	0.26	BDL	0.55	0.26	7.14	0.38	7.40	0.09	34.468	0.15	25.1	8.11	99.3
MAKENA 2	0 S	1	0.23	4.51	0.22	18.00	0.23	7.62	0.46	12.35	0.50	33.600	1.12	NA	8.10	NA
	2 S	1	0.24	4.63	0.32	18.04	0.21	6.78	0.45	11.73	0.48	33.599	1.11	NA	8.10	NA
	5 S	1	0.23	4.88	0.33	17.92	0.22	6.47	0.45	11.68	0.32	33.638	0.72	NA	8.09	NA
	5 D	1.5	0.21	3.79	0.22	14.15	0.25	7.78	0.46	11.79	0.31	33.860	0.88	NA	8.10	NA
	10 S	1	0.17	1.29	0.19	5.44	0.21	7.48	0.38	8.96	0.36	34.300	0.42	24.6	8.10	99.8
	10 D	2.5	0.14	0.96	0.41	4.36	0.28	7.31	0.42	8.68	0.32	34.348	0.66	25.0	8.10	97.9
	50 S	1	0.14	1.60	0.41	6.53	0.32	6.98	0.46	8.99	0.19	34.244	0.41	24.8	8.09	98.8
	50 D	4.5	0.09	0.54	0.20	2.40	0.34	6.26	0.43	7.00	0.14	34.436	0.46	25.0	8.10	97.3
	100 S	1	0.08	0.42	0.30	1.11	0.32	7.01	0.40	7.73	0.07	34.502	0.27	25.0	8.11	97.6
	100 D	7.5	0.08	0.41	0.10	1.14	0.31	5.77	0.39	6.28	0.08	34.489	0.34	25.1	8.11	98.1
	150 S	1	0.09	0.44	0.27	1.33	0.33	6.14	0.42	6.85	0.10	34.482	0.17	25.0	8.11	98.7
	150 D	11	0.08	0.34	0.06	1.58	0.36	6.30	0.44	6.70	0.10	34.474	0.34	25.0	8.11	98.3
	200 S	1	0.08	0.38	0.08	1.41	0.35	6.47	0.43	6.93	0.08	34.477	0.26	25.0	8.11	98.7
	200 D	15	0.08	0.05	0.23	1.05	0.31	6.56	0.39	6.84	0.10	34.505	0.18	25.1	8.12	99.3
MAKENA 3	0 S	1	0.11	2.60	0.50	7.76	0.29	7.20	0.40	10.30	0.35	34.348	0.46	NA	8.18	NA
	2 S	1	0.24	13.86	0.31	19.31	0.28	6.08	0.52	20.25	0.78	33.980	0.61	NA	8.06	NA
	5 S	1	0.16	5.07	0.45	9.36	0.28	7.09	0.44	12.61	0.41	34.285	0.42	NA	8.07	NA
	5 D	3	0.13	2.53	0.33	5.63	0.27	6.19	0.40	9.05	0.28	34.400	0.51	NA	8.08	NA
	10 S	1	0.10	0.68	0.33	1.99	0.28	7.44	0.38	8.45	0.14	34.516	0.39	24.8	8.07	97.2
	10 D	4.5	0.10	0.66	0.38	1.98	0.30	6.56	0.40	7.60	0.14	34.470	0.37	24.9	8.08	93.2
	50 S	1	0.09	0.26	0.15	1.22	0.30	7.30	0.39	7.71	0.11	34.478	0.19	24.9	8.12	101.1
	50 D	9	0.09	0.27	0.11	1.19	0.30	6.97	0.39	7.35	0.10	34.472	0.24	25.0	8.12	97.8
	100 S	1	0.09	0.20	0.24	1.62	0.31	6.54	0.40	6.98	0.09	34.478	0.14	24.9	8.13	102.6
	100 D	15	0.09	0.18	0.31	1.94	0.30	5.89	0.39	6.38	0.09	34.485	0.17	25.1	8.13	99.7
	150 S	1	0.09	0.18	0.04	1.31	0.29	6.28	0.38	6.50	0.07	34.482	0.12	25.0	8.13	98.9
	150 D	15	0.09	0.15	0.08	1.39	0.30	6.34	0.39	6.57	0.07	34.467	0.13	25.1	8.13	99.4
MAKENA 4	0 S	1	0.47	11.26	0.31	70.14	0.19	7.25	0.66	18.82	0.20	31.835	2.15	NA	7.98	NA
	2 S	1	0.43	9.11	0.36	60.15	0.20	8.55	0.63	18.02	0.18	32.395	0.80	NA	7.96	NA
	5 S	1	0.16	1.49	0.32	9.26	0.27	6.97	0.43	8.78	0.16	34.249	0.49	NA	7.98	NA
	5 D	1.5	0.12	0.90	0.45	5.66	0.29	7.73	0.41	9.08	0.17	34.349	0.87	NA	7.99	NA
	10 S	1	0.11	0.51	0.42	3.69	0.28	6.72	0.39	7.65	0.15	34.400	0.33	24.6	7.99	90.9
	10 D	2.5	0.15	0.57	0.41	4.36	0.36	7.24	0.51	8.22	0.18	34.443	0.41	24.7	7.98	87.3
	50 S	1	0.08	0.40	0.27	3.02	0.30	9.13	0.38	9.80	0.16	34.420	0.42	24.7	7.99	94.4
	50 D	9	0.10	0.41	0.29	3.20	0.30	7.35	0.40	8.05	0.13	34.427	0.31	24.9	8.01	89.1
	100 S	1	0.11	0.43	0.13	3.08	0.31	7.05	0.42	7.61	0.09	34.466	0.18	24.8	8.07	89.1
	100 D	14	0.12	0.40	0.21	2.78	0.28	6.54	0.40	7.15	0.10	34.480	0.22	24.8	8.06	86.2
	150 S	1	0.11	0.34	0.08	2.82	0.31	9.28	0.42	9.70	0.17	34.507	0.19	24.9	8.09	97.3
	150 D	18	0.18	0.31	0.11	2.42	0.32	8.18	0.50	8.60	0.12	34.517	0.22	24.9	8.09	93.0
DOH WQS	DRY	10%		0.71	0.36				0.96	12.86	0.50	*	0.50	**	***	
	WET	2%		1.43	0.64				1.45	17.86	1.00		1.00			
	DRY	10%		1.00	0.60				1.29	17.85	1.25	*	0.90	**	***	
	WET	2%		1.78	1.07				1.93	25.00	2.00		1.75			

* Salinity shall not vary more than ten percent from natural or seasonal changes considering hydrologic input and oceanographic conditions.

** Temperature shall not vary by more than one degree C. from ambient conditions.

***pH shall not deviate more than 0.5 units from a value of 8.1.

TABLE 2. Water chemistry measurements from ocean water samples (in µg/L) collected in the vicinity of the Makena Golf Course on March 6, 2004. Nutrient concentrations are shown as micrograms per liter (µg/L). Abbreviations as follows: DFS=distance from shore;S=surface; D=deep, BDL=below detection limit, NA=data not available. Also shown are the State of Hawaii, Department of Health (DOH) "not to exceed more than 10% of the time" and "not to exceed more than 2% of the time" water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH 10% "dry" standards; boxed and shaded values exceed DOH 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT	DFS (m)	DEPTH (m)	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (NTU)	SALINITY (‰)	CHL a (µg/L)	TEMP (deg.C)	pH (std.units)	O2 % Sat
MAKENA 1	0 S	1	25.11	1680.70	18.49	4201.8	1.24	104.58	26.35	1803.76	0.22	25.259	0.79	NA	7.93	NA
	2 S	1	8.37	498.96	3.92	1226.8	3.41	134.26	11.78	637.14	0.17	31.990	0.77	NA	8.05	NA
	5 S	1	5.89	272.16	3.92	718.5	3.72	103.32	9.61	379.40	0.16	33.109	0.36	NA	8.06	NA
	5 D	2.5	5.89	198.24	4.06	538.7	6.82	104.02	12.71	306.32	0.13	33.465	0.34	NA	8.06	NA
	10 S	1	5.58	102.06	4.48	280.4	8.37	110.60	13.95	217.14	0.14	33.979	0.33	24.9	8.05	100.2
	10 D	3	4.65	37.38	4.48	105.1	8.99	116.20	13.64	158.06	0.12	34.322	0.37	25.0	8.05	93.2
	50 S	1	5.58	109.20	4.34	304.0	9.92	126.28	15.50	239.82	0.13	33.948	0.31	24.8	8.04	96.4
	50 D	4.5	4.03	12.60	2.94	44.1	8.06	102.06	12.09	117.60	0.10	34.482	0.22	25.1	8.02	99.6
	100 S	1	4.96	34.16	2.24	103.1	8.68	102.06	13.64	138.46	0.11	34.385	0.26	25.0	8.06	97.7
	100 D	10	3.72	3.22	BDL	18.5	9.30	101.08	13.02	104.30	0.10	34.542	0.20	25.0	8.11	98.2
	150 S	1	4.96	81.34	1.40	282.7	7.13	89.88	12.09	172.62	0.09	34.358	0.17	25.0	8.06	99.0
	150 D	15	3.72	3.64	BDL	15.5	8.06	99.96	11.78	103.60	0.09	34.468	0.15	25.1	8.11	99.3
MAKENA 2	0 S	1	7.13	63.14	3.08	505.8	7.13	106.68	14.26	172.90	0.50	33.600	1.12	NA	8.10	NA
	2 S	1	7.44	64.82	4.48	506.9	6.51	94.92	13.95	164.22	0.48	33.599	1.11	NA	8.10	NA
	5 S	1	7.13	68.32	4.62	503.6	6.82	90.58	13.95	163.52	0.32	33.638	0.72	NA	8.09	NA
	5 D	1.5	6.51	53.06	3.08	397.6	7.75	108.92	14.26	165.06	0.31	33.860	0.88	NA	8.10	NA
	10 S	1	5.27	18.06	2.66	152.9	6.51	104.72	11.78	125.44	0.36	34.300	0.42	24.6	8.10	99.8
	10 D	2.5	4.34	13.44	5.74	122.5	8.68	102.34	13.02	121.52	0.32	34.348	0.66	25.0	8.10	97.9
	50 S	1	4.34	22.40	5.74	183.5	9.92	97.72	14.26	125.86	0.19	34.244	0.41	24.8	8.09	98.8
	50 D	4.5	2.79	7.56	2.80	67.4	10.54	87.64	13.33	98.00	0.14	34.436	0.46	25.0	8.10	97.3
	100 S	1	2.48	5.88	4.20	31.2	9.92	98.14	12.40	108.22	0.07	34.502	0.27	25.0	8.11	97.6
	100 D	7.5	2.48	5.74	1.40	32.0	9.61	80.78	12.09	87.92	0.08	34.489	0.34	25.1	8.11	98.1
	150 S	1	2.79	6.16	3.78	37.4	10.23	85.96	13.02	95.90	0.10	34.482	0.17	25.0	8.11	98.7
	150 D	11	2.48	4.76	0.84	44.4	11.16	88.20	13.64	93.80	0.10	34.474	0.34	25.0	8.11	98.3
	200 S	1	2.48	5.32	1.12	39.6	10.85	90.58	13.33	97.02	0.08	34.477	0.26	25.0	8.11	98.7
	200 D	15	2.48	0.70	3.22	29.5	9.61	91.84	12.09	95.76	0.10	34.505	0.18	25.1	8.12	99.3
MAKENA 3	0 S	1	3.41	36.40	7.00	218.1	8.99	100.80	12.40	144.20	0.35	34.348	0.46	NA	8.18	NA
	2 S	1	7.44	194.04	4.34	542.6	8.68	85.12	16.12	283.50	0.78	33.980	0.61	NA	8.06	NA
	5 S	1	4.96	70.98	6.30	263.0	8.68	99.26	13.64	176.54	0.41	34.285	0.42	NA	8.07	NA
	5 D	3	4.03	35.42	4.62	158.2	8.37	86.66	12.40	126.70	0.28	34.400	0.51	NA	8.08	NA
	10 S	1	3.10	9.52	4.62	55.9	8.68	104.16	11.78	118.30	0.14	34.516	0.39	24.8	8.07	97.2
	10 D	4.5	3.10	9.24	5.32	55.6	9.29	91.88	12.39	106.45	0.14	34.470	0.37	24.9	8.08	93.2
	50 S	1	2.79	3.64	2.10	34.3	9.30	102.20	12.09	107.94	0.11	34.478	0.19	24.9	8.12	101.1
	50 D	9	2.79	3.78	1.54	33.4	9.30	97.58	12.09	102.90	0.10	34.472	0.24	25.0	8.12	97.8
	100 S	1	2.79	2.80	3.36	45.5	9.61	91.56	12.40	97.72	0.09	34.478	0.14	24.9	8.13	102.6
	100 D	15	2.79	2.52	4.34	54.5	9.30	82.46	12.09	89.32	0.09	34.485	0.17	25.1	8.13	99.7
	150 S	1	2.79	2.52	0.56	36.8	8.99	87.92	11.78	91.00	0.07	34.482	0.12	25.0	8.13	98.9
	150 D	15	2.79	2.10	1.12	39.1	9.30	88.76	12.09	91.98	0.07	34.467	0.13	25.1	8.13	99.4
MAKENA 4	0 S	1	14.57	157.64	4.34	1970.9	5.89	101.50	20.46	263.48	0.20	31.835	2.15	NA	7.98	NA
	2 S	1	13.33	127.54	5.04	1690.2	6.20	119.70	19.53	252.28	0.18	32.395	0.80	NA	7.96	NA
	5 S	1	4.96	20.86	4.48	260.2	8.37	97.58	13.33	122.92	0.16	34.249	0.49	NA	7.98	NA
	5 D	1.5	3.72	12.60	6.30	159.0	8.99	108.22	12.71	127.12	0.17	34.349	0.87	NA	7.99	NA
	10 S	1	3.41	7.14	5.88	103.7	8.68	94.08	12.09	107.10	0.15	34.400	0.33	24.6	7.99	90.9
	10 D	2.5	4.65	7.98	5.74	122.5	11.16	101.36	15.81	115.08	0.18	34.443	0.41	24.7	7.98	87.3
	50 S	1	2.48	5.60	3.78	84.9	9.30	127.82	11.78	137.20	0.16	34.420	0.42	24.7	7.99	94.4
	50 D	9	3.10	5.74	4.06	89.9	9.30	102.90	12.40	112.70	0.13	34.427	0.31	24.9	8.01	89.1
	100 S	1	3.41	6.02	1.82	86.5	9.61	98.70	13.02	106.54	0.09	34.466	0.18	24.8	8.07	89.1
	100 D	14	3.72	5.60	2.94	78.1	8.68	91.56	12.40	100.10	0.10	34.480	0.22	24.8	8.06	86.2
	150 S	1	3.41	4.76	1.12	79.2	9.61	129.92	13.02	135.80	0.17	34.507	0.19	24.9	8.09	97.3
	150 D	18	5.58	4.34	1.54	68.0	9.92	114.52	15.50	120.40	0.12	34.517	0.22	24.9	8.09	93.0
DOH WQS	DRY	10%		10.00	5.00				30.00	180.00	0.50	*	0.50	**	***	
	WET	2%		20.00	9.00				45.00	250.00	1.00	*	1.00	**	***	
	DRY	10%		14.00	8.50				40.00	250.00	1.25	*	0.90	**	***	
	WET	2%		25.00	15.00				60.00	350.00	2.00	*	1.75	**	***	

* Salinity shall not vary more than ten percent from natural or seasonal changes considering hydrologic input and oceanographic conditions.

** Temperature shall not vary by more than one degree C. from ambient conditions.

***pH shall not deviate more than 0.5 units from a value of 8.1.

TABLE 3. Geometric means of water chemistry measurements (nutrient concentrations shown in micromolar [μM] units) off the Makena Golf Course collected since August 1995 (N=13). For geometric mean calculations, detection limits were used in cases where sample was below detection limit. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep. Also shown are State of Hawaii, Department of Health (DOH) geometric mean water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH GM 10% "dry" standards; boxed and shaded values exceed DOH GM 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT	DFS (m)	DEPTH (m)	PO4 (μM)	NO3 (μM)	NH4 (μM)	Si (μM)	TOP (μM)	TON (μM)	TP (μM)	TN (μM)	TURB (NTU)	SALINITY (‰)	CHL a ($\mu\text{g/L}$)	TEMP (deg.C)	pH
MAKENA 1	0 S	1	0.21	33.56	0.33	57.74	0.22	7.84	0.49	44.43	0.32	30.499	0.81	25.3	8.16
	2 S	1	0.15	22.35	0.24	39.67	0.24	7.58	0.41	31.29	0.26	32.185	0.77	25.3	8.18
	5 S	1	0.13	10.38	0.18	21.56	0.25	7.56	0.39	20.96	0.22	33.158	0.62	25.4	8.18
	5 D	2.5	0.12	8.84	0.28	19.21	0.27	7.23	0.41	19.12	0.20	33.337	0.72	25.4	8.17
	10 S	1	0.10	3.62	0.16	9.73	0.25	6.77	0.37	11.85	0.19	34.196	0.38	25.4	8.16
	10 D	3	0.11	2.70	0.20	7.70	0.27	7.05	0.39	10.58	0.19	34.373	0.43	25.4	8.15
	50 S	1	0.11	2.71	0.18	7.44	0.26	6.67	0.38	10.72	0.16	34.362	0.30	25.5	8.15
	50 D	4.5	0.10	0.38	0.12	2.90	0.27	7.10	0.38	7.78	0.11	34.766	0.27	25.5	8.15
	100 S	1	0.10	1.04	0.13	5.25	0.26	6.23	0.37	9.37	0.12	34.518	0.27	25.5	8.14
	100 D	10	0.09	0.09	0.07	2.13	0.27	6.81	0.37	7.09	0.09	34.803	0.23	25.5	8.16
	150 S	1	0.09	0.31	0.10	3.47	0.26	6.58	0.36	7.87	0.12	34.706	0.20	25.6	8.15
	150 D	15	0.09	0.07	0.08	1.93	0.26	6.56	0.36	6.82	0.09	34.810	0.17	25.5	8.16
	200 S	1	0.24	4.07	0.33	21.81	0.33	7.78	0.61	12.87	1.01	33.800	0.89	25.4	8.15
	200 D	15	0.09	0.06	0.19	1.94	0.29	7.52	0.39	7.90	0.10	34.838	0.29	25.5	8.17
MAKENA 2	0 S	1	0.24	3.97	0.28	19.63	0.34	7.74	0.62	12.69	0.81	33.786	0.97	25.4	8.15
	2 S	1	0.24	3.54	0.29	15.76	0.29	6.59	0.51	11.23	0.49	33.991	0.66	25.4	8.15
	5 S	1	0.21	3.42	0.39	16.15	0.32	6.88	0.56	11.88	0.51	34.002	0.85	25.4	8.14
	5 D	1.5	0.21	1.98	0.21	10.32	0.31	4.29	0.50	9.03	0.37	34.326	0.46	25.3	8.15
	10 S	1	0.16	1.54	0.33	8.85	0.33	6.99	0.51	9.45	0.31	34.425	0.55	25.4	8.15
	10 D	2.5	0.15	1.37	0.28	8.58	0.33	7.05	0.50	9.17	0.31	34.424	0.39	25.4	8.14
	50 S	1	0.14	0.30	0.20	3.58	0.33	7.40	0.46	8.12	0.21	34.753	0.52	25.4	8.15
	50 D	4.5	0.11	0.56	0.20	4.44	0.29	7.17	0.41	8.32	0.17	34.628	0.30	25.5	8.14
	100 S	1	0.10	0.20	0.18	2.71	0.29	6.80	0.39	7.32	0.13	34.774	0.31	25.5	8.16
	100 D	7.5	0.09	0.29	0.23	3.35	0.29	7.17	0.41	7.81	0.13	34.736	0.26	25.5	8.15
	150 S	1	0.10	0.21	0.18	2.46	0.30	7.54	0.41	7.97	0.11	34.792	0.26	25.5	8.16
	150 D	11	0.09	0.13	0.18	2.69	0.28	6.97	0.38	7.71	0.11	34.799	0.24	25.6	8.16
	200 S	1	0.09	0.06	0.19	1.94	0.29	7.52	0.39	7.90	0.10	34.838	0.29	25.5	8.17
	200 D	15	0.09	0.06	0.19	1.94	0.29	7.52	0.39	7.90	0.10	34.838	0.29	25.5	8.17
MAKENA 3	0 S	1	0.11	0.76	0.31	4.81	0.28	6.88	0.42	9.91	0.29	34.602	0.37	25.2	8.18
	2 S	1	0.14	1.11	0.31	5.95	0.29	6.97	0.46	12.06	0.30	34.456	0.39	25.3	8.16
	5 S	1	0.14	0.88	0.25	5.45	0.27	6.83	0.42	10.84	0.21	34.550	0.29	25.3	8.16
	5 D	3	0.13	0.76	0.29	5.27	0.28	6.79	0.42	10.55	0.23	34.580	0.35	25.3	8.16
	10 S	1	0.11	0.48	0.30	3.67	0.29	7.00	0.41	9.32	0.17	34.699	0.23	25.2	8.15
	10 D	4.5	0.11	0.36	0.24	3.34	0.28	6.81	0.40	8.50	0.17	34.734	0.28	25.3	8.16
	50 S	1	0.09	0.26	0.24	2.93	0.27	6.79	0.38	8.02	0.13	34.760	0.20	25.4	8.14
	50 D	9	0.09	0.17	0.24	2.54	0.28	6.89	0.38	7.52	0.13	34.810	0.19	25.3	8.16
	100 S	1	0.08	0.11	0.20	2.24	0.28	6.84	0.37	7.36	0.11	34.799	0.14	25.4	8.16
	100 D	15	0.08	0.08	0.19	2.05	0.28	6.54	0.37	6.96	0.10	34.824	0.17	25.3	8.16
	150 S	1	0.06	0.07	0.18	2.07	0.27	6.37	0.35	6.85	0.09	34.806	0.15	25.4	8.16
	150 D	15	0.08	0.05	0.16	1.98	0.28	6.38	0.37	6.71	0.09	34.815	0.19	25.4	8.17
	200 S	1	0.40	7.64	0.33	63.41	0.26	7.01	0.70	17.80	0.33	31.245	0.69	24.9	8.04
	200 D	15	0.09	0.06	0.19	1.94	0.29	7.52	0.39	7.90	0.10	34.838	0.29	25.5	8.17
MAKENA 4	0 S	1	0.50	10.61	0.35	84.57	0.21	6.55	0.79	21.51	0.35	29.390	0.79	24.8	8.03
	2 S	1	0.40	7.64	0.33	63.41	0.26	7.01	0.70	17.80	0.33	31.245	0.69	24.9	8.04
	5 S	1	0.17	1.01	0.19	13.45	0.25	6.83	0.44	8.70	0.21	34.147	0.37	25.0	8.07
	5 D	1.5	0.16	0.82	0.25	12.17	0.25	6.80	0.44	8.50	0.19	34.201	0.41	25.0	8.07
	10 S	1	0.16	0.73	0.26	10.47	0.25	6.69	0.43	8.08	0.20	34.312	0.28	25.0	8.07
	10 D	2.5	0.14	0.49	0.29	9.33	0.25	7.01	0.41	8.31	0.19	34.360	0.30	25.0	8.08
	50 S	1	0.11	0.42	0.25	6.32	0.27	7.80	0.39	8.80	0.16	34.561	0.25	25.0	8.10
	50 D	9	0.11	0.22	0.18	4.09	0.27	7.37	0.40	7.89	0.14	34.749	0.24	25.1	8.11
	100 S	1	0.10	0.22	0.17	4.26	0.27	7.12	0.38	7.64	0.12	34.751	0.18	25.1	8.13
	100 D	14	0.11	0.19	0.24	3.15	0.27	6.94	0.39	7.60	0.10	34.781	0.20	25.2	8.13
	150 S	1	0.11	0.11	0.14	2.57	0.23	7.21	0.45	7.70	0.10	34.808	0.15	25.3	8.15
	150 D	18	0.10	0.13	0.14	2.23	0.27	7.15	0.38	7.57	0.07	34.827	0.15	25.3	8.16
	DOH WQS	GM	DRY		0.25	0.14			0.52	7.86	0.20	*	0.15	**	***
			WET		0.36	0.25			0.64	10.71	0.50		0.30		

* Salinity shall not vary more than ten percent from natural or seasonal changes considering hydrologic input and oceanographic conditions.

** Temperature shall not vary by more than one degree C. from ambient conditions.

***pH shall not deviate more than 0.5 units from a value of 8.1.

TABLE 4. Geometric means of water chemistry measurements (nutrient concentrations shown as micrograms per liter [µg/L]) off the Makena Golf Course collected since August 1995 (N=13). For geometric mean calculations, detection limits were used in cases where sample was below detection limit. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep. Also shown are State of Hawaii, Department of Health (DOH) geometric mean water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH GM 10% "dry" standards; boxed and shaded values exceed DOH GM 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT	DFS (m)	DEPTH (m)	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (NTU)	SALINITY (‰)	CHL a (µg/L)	TEMP (deg.C)	pH
MAKENA 1	0 S	1	6.50	470.00	4.60	1621.9	6.80	109.80	15.10	622.20	0.32	30.499	0.81	25.3	8.16
	2 S	1	4.60	313.00	3.30	1114.3	7.40	106.10	12.60	438.20	0.26	32.185	0.77	25.3	8.18
	5 S	1	4.00	145.30	2.50	605.6	7.70	105.80	12.00	293.50	0.22	33.158	0.62	25.4	8.18
	5 D	2.5	3.70	123.80	3.90	539.6	8.30	101.20	12.60	267.70	0.20	33.337	0.72	25.4	8.17
	10 S	1	3.00	50.70	2.20	273.3	7.70	94.80	11.40	165.90	0.19	34.196	0.38	25.4	8.16
	10 D	3	3.40	37.80	2.80	216.3	8.30	98.70	12.00	148.10	0.19	34.373	0.43	25.4	8.15
	50 S	1	3.40	37.90	2.50	209.0	8.00	93.40	11.70	150.10	0.16	34.362	0.30	25.5	8.15
	50 D	4.5	3.00	5.30	1.60	81.5	8.30	99.40	11.70	108.90	0.11	34.766	0.27	25.5	8.15
	100 S	1	3.00	14.50	1.80	147.5	8.00	87.20	11.40	131.20	0.12	34.518	0.27	25.5	8.14
	100 D	10	2.70	1.20	0.90	59.8	8.30	95.30	11.40	99.30	0.09	34.803	0.23	25.5	8.16
	150 S	1	2.70	4.30	1.40	97.5	8.00	92.10	11.10	110.20	0.12	34.706	0.20	25.6	8.15
	150 D	15	2.70	0.90	1.10	54.2	8.00	91.80	11.10	95.50	0.09	34.810	0.17	25.5	8.16
MAKENA 2	0 S	1	7.40	57.00	4.60	612.6	10.20	108.90	18.80	180.20	1.01	33.800	0.89	25.4	8.15
	2 S	1	7.40	55.60	3.90	551.4	10.50	108.40	19.20	177.70	0.81	33.786	0.97	25.4	8.15
	5 S	1	6.50	49.50	4.00	442.7	8.90	92.20	15.70	157.20	0.49	33.991	0.66	25.4	8.15
	5 D	1.5	6.50	47.90	5.40	453.7	9.90	96.30	17.30	166.30	0.51	34.002	0.85	25.4	8.14
	10 S	1	4.90	27.70	2.90	289.9	9.60	60.00	15.40	126.40	0.37	34.326	0.46	25.3	8.15
	10 D	2.5	4.60	21.50	4.60	248.6	10.20	97.90	15.70	132.30	0.31	34.425	0.55	25.4	8.15
	50 S	1	4.30	19.10	3.90	241.0	10.20	98.70	15.40	128.40	0.31	34.424	0.39	25.4	8.14
	50 D	4.5	3.40	4.20	2.80	100.6	10.20	103.60	14.20	113.70	0.21	34.753	0.52	25.4	8.15
	100 S	1	3.00	7.80	2.80	124.7	8.90	100.40	12.60	116.50	0.17	34.628	0.30	25.5	8.14
	100 D	7.5	2.70	2.80	2.50	76.1	8.90	95.20	12.00	102.50	0.13	34.774	0.31	25.5	8.16
	150 S	1	3.00	4.00	3.20	94.1	8.90	100.40	12.60	109.30	0.13	34.736	0.26	25.5	8.15
	150 D	11	2.70	1.80	2.50	69.1	9.20	105.60	12.60	111.60	0.11	34.792	0.26	25.5	8.16
	200 S	1	2.70	2.90	2.50	75.6	8.60	97.60	11.70	107.90	0.11	34.799	0.24	25.6	8.16
	200 D	15	2.70	0.80	2.60	54.5	8.90	105.30	12.00	110.60	0.10	34.838	0.29	25.5	8.17
MAKENA 3	0 S	1	3.40	10.60	4.30	135.1	8.60	96.30	13.00	138.70	0.29	34.602	0.37	25.2	8.18
	2 S	1	4.30	15.50	4.30	167.1	8.90	97.60	14.20	168.90	0.30	34.456	0.39	25.3	8.16
	5 S	1	4.30	12.30	3.50	153.1	8.30	95.60	13.00	151.80	0.21	34.550	0.29	25.3	8.16
	5 D	3	4.00	10.60	4.00	148.0	8.60	95.10	13.00	147.70	0.23	34.580	0.35	25.3	8.16
	10 S	1	3.40	6.70	4.20	103.1	8.90	98.00	12.60	130.50	0.17	34.699	0.23	25.2	8.15
	10 D	4.5	3.40	5.00	3.30	93.8	8.60	95.30	12.30	119.00	0.17	34.734	0.28	25.3	8.16
	50 S	1	2.70	3.60	3.30	82.3	8.30	95.10	11.70	112.30	0.13	34.760	0.20	25.4	8.14
	50 D	9	2.70	2.30	3.30	71.3	8.60	96.50	11.70	105.30	0.13	34.810	0.19	25.3	8.16
	100 S	1	2.40	1.50	2.80	62.9	8.60	95.80	11.40	103.00	0.11	34.799	0.14	25.4	8.16
	100 D	15	2.40	1.10	2.60	57.6	8.60	91.50	11.40	97.40	0.10	34.824	0.17	25.3	8.16
	150 S	1	1.80	0.90	2.50	58.1	8.30	89.20	10.80	95.90	0.09	34.806	0.15	25.4	8.16
	150 D	15	2.40	0.70	2.20	55.6	8.60	89.30	11.40	93.90	0.09	34.815	0.19	25.4	8.17
MAKENA 4	0 S	1	15.40	148.60	4.90	2375.6	6.50	91.70	24.40	301.20	0.35	29.390	0.79	24.8	8.03
	2 S	1	12.30	107.00	4.60	1781.2	8.00	98.10	21.60	249.30	0.33	31.245	0.69	24.9	8.04
	5 S	1	5.20	14.10	2.60	377.8	7.70	95.60	13.60	121.80	0.21	34.147	0.37	25.0	8.07
	5 D	1.5	4.90	11.40	3.50	341.9	7.70	95.20	13.60	119.00	0.19	34.201	0.41	25.0	8.07
	10 S	1	4.90	10.20	3.60	294.1	7.70	93.70	13.30	113.10	0.20	34.312	0.28	25.0	8.07
	10 D	2.5	4.30	6.80	4.00	262.1	7.70	98.10	12.60	116.30	0.19	34.360	0.30	25.0	8.08
	50 S	1	3.40	5.80	3.50	177.5	8.30	109.20	12.00	123.20	0.16	34.561	0.25	25.0	8.1
	50 D	9	3.40	3.00	2.50	114.9	8.30	103.20	12.30	110.50	0.14	34.749	0.24	25.1	8.11
	100 S	1	3.00	3.00	2.30	119.7	8.30	99.70	11.70	107.00	0.12	34.751	0.18	25.1	8.13
	100 D	14	3.40	2.60	3.30	88.5	8.30	97.20	12.00	106.40	0.10	34.781	0.20	25.2	8.13
	150 S	1	3.40	1.50	1.90	72.2	7.10	100.90	13.90	107.80	0.10	34.808	0.15	25.3	8.15
	150 D	18	3.00	1.80	1.90	62.6	8.30	100.10	11.70	106.00	0.07	34.827	0.15	25.3	8.16
DOH WQS	GM	DRY		3.50	2.00				16.00	110.00	0.20	*	0.15	**	***
		WET		5.00	3.50				20.00	150.00	0.50		0.30		

* Salinity shall not vary more than ten percent from natural or seasonal changes considering hydrologic input and oceanographic conditions.

** Temperature shall not vary by more than one degree C. from ambient conditions.

***pH shall not deviate more than 0.5 units from a value of 8.1.

TABLE 5. Water chemistry measurements in μM and $\mu\text{g/L}$ (shaded) from irrigation wells and an irrigation lake and three of six lysimeters collected in the vicinity of the Makena Golf Course in March 2004. For sampling site locations, see Figure 1.

WELLS	PO4 (μM)	PO4 ($\mu\text{g/L}$)	NO3 (μM)	NO3 ($\mu\text{g/L}$)	NH4 (μM)	NH4 ($\mu\text{g/L}$)	Si (μM)	Si ($\mu\text{g/L}$)	TOP (μM)	TOP ($\mu\text{g/L}$)	TON (μM)	TON ($\mu\text{g/L}$)	TP (μM)	TP ($\mu\text{g/L}$)	TN (μM)	TN ($\mu\text{g/L}$)	SALINITY (ppt)
1	1.70	52.70	136.70	1,913.80	3.90	54.60	555.30	15,603.93	0.40	12.40	20.50	287.00	2.10	65.10	161.10	2,255.40	1.29
2	1.90	58.90	120.80	1,691.20	3.30	46.20	714.30	20,071.83	0.80	24.80	34.20	478.80	2.70	83.70	158.30	2,216.20	1.67
3	2.60	80.60	144.70	2,025.80	3.90	54.60	747.80	21,013.18	0.40	12.40	26.50	371.00	3.00	93.00	175.10	2,451.40	1.87
4	2.30	71.30	154.70	2,165.80	4.50	63.00	688.50	19,346.85	0.00	0.00	28.80	403.20	2.30	71.30	188.00	2,632.00	1.98
5	1.60	49.60	104.20	1,458.80	3.90	54.60	554.60	15,584.26	0.60	18.60	25.90	362.60	2.20	68.20	134.00	1,876.00	1.54
6	2.10	65.10	199.20	2,788.80	4.10	57.40	567.50	15,946.75	0.30	9.30	30.40	425.60	2.40	74.40	233.70	3,271.80	1.49
10	2.30	71.30	185.60	2,598.40	5.20	72.80	668.60	18,787.66	0.10	3.10	38.00	532.00	2.40	74.40	228.80	3,203.20	2.34
LYSIMETERS																	
Hole 3	35.75	1,108.25	181.50	2,541.00	108.75	1,522.50	631.00	17,731.10	55.00	1,705.00	1,550.75	21,710.50	90.75	2,813.25	1,841.00	25,774.00	1.45
Hole 15	72.75	2,255.25	3.75	52.50	1.50	21.00	642.00	18,040.20	47.75	1,480.25	1,292.25	18,091.50	120.50	3,735.50	1,297.50	18,165.00	1.26