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Mākena Golf & Beach Club quarterly water quality monitoring report

September 2022

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Introduction

The State Land Use Commission requires that Mākena Golf and Beach Club (MG&BC; called "Project" herein) submit water quality monitoring reports to the Hawai'i Department of Health (HDOH) in compliance with Condition No. 10 in the "Declaration of Conditions", a document that pertains to the Amendment of the MG&BC District Boundary, dated April 17, 1998. The monitoring report must also ensure compliance with Condition 19 of the County of Maui, Zoning Ordinance 3613. The goals of the monitoring program established to comply with Condition No. 10 and Ordinance 3613 are: (1) assess degree to which fertilizers, as well as other nutrient sources used on land to enhance golf course turf growth and resort landscaping, leach to groundwater and subsequently reach nearshore waters; (2) establish evidence of delivery of these nutrients into the nearshore environment; and (3) determine if subsequent water quality has any measurable impacts on biological community structure in the nearshore marine environment (see annual water quality reports: *AECOS*, 2019a,b, 2021, 2022)

Water quality parameters of particular interest for the purposes of our monitoring program are termed nutrients[1]. Nutrient enrichment can enhance nuisance algae production in aquatic environments (HDLNR, 2014). Nutrient enrichment can also negatively impact corals and other biological components in Hawai'i coastal waters (Laws et al., 2004; MRC, 2011; *AECOS*, 2016). A

[1] "Nutrients" are nitrogen and phosphorus compounds that promote plant growth, including algal growth in the marine environment. These chemicals are the main ingredients in applied fertilizers.

separate program monitors nearshore biological assemblages off the MG&BC resort to determine if marine water quality is impacting the biota extant there (see *AECOS*, 2020).

Tables and figures throughout this quarterly report compare the most recent (September 1, 2022) water quality monitoring results with means calculated from 17 previous monitoring events undertaken quarterly between June 2018 and June 2022.

Background

Waters south from Nahuna Point—including Mākena Bay and Maluaka Bay (Figure 1)—to Pu'u Ola'i are designated as "Class A, open coastal waters" in State of Hawai'i water quality standards (HDOH, 2021). These waters are included on the HDOH 2020 list of impaired waters in Hawai'i prepared under Clean Water Act §303(d) as impaired for nitrate+nitrite, ammonium, total nitrogen, turbidity, and chlorophyll α (HDOH, 2022). These waters are listed as "Category 2" (meaning that some designated uses are attained), "Category 3" (meaning that insufficient data and/or information exist to make use-support determinations), and "Category 5" (meaning that available data and/or information indicate that at least one designated use is not supported or is threatened). These results indicate that a Total Maximum Daily Load[2] study may be needed.

Marine waters from Pu'u Ola'i south are designated as Class AA "open coastal waters" in State of Hawai'i water quality standards (HDOH, 2021) and included on the HDOH 2022 list of impaired waters in Hawai'i for nitrate+nitrite, ammonium, and turbidity (HDOH, 2022). These waters are also listed under Categories 2, 3 and 5.

Methods

The September 1, 2022 quarterly monitoring event was conducted along three monitoring transects in nearshore waters adjacent to MG&BC (Transects M-1, M-2, and M-3) and at a control site located well south of Pu'u Ola'i (Transect M-4) (Figure 1). Sampling stations were set at 2-m, 10-m, 50-m, and 100-m

[2] Total Maximum Daily Load (TMDL) studies are done to establish limits on point-source discharges of substances causing impairments to water quality in aquatic environments. The term "needed" in the HDOH document actually means "has not been done". A TMDL for any particular location is undertaken by HDOH and is unrelated to this monitoring effort as no point-source discharge is existing or contemplated at Mākena.

distance from shore along each transect and water samples were collected from near the surface at each station. Water quality samples were also obtained from four source water wells: Mākena Well 1, Mākena Well 3, Mākena Well 4 and Mākena Well 6 (see Fig. 1).

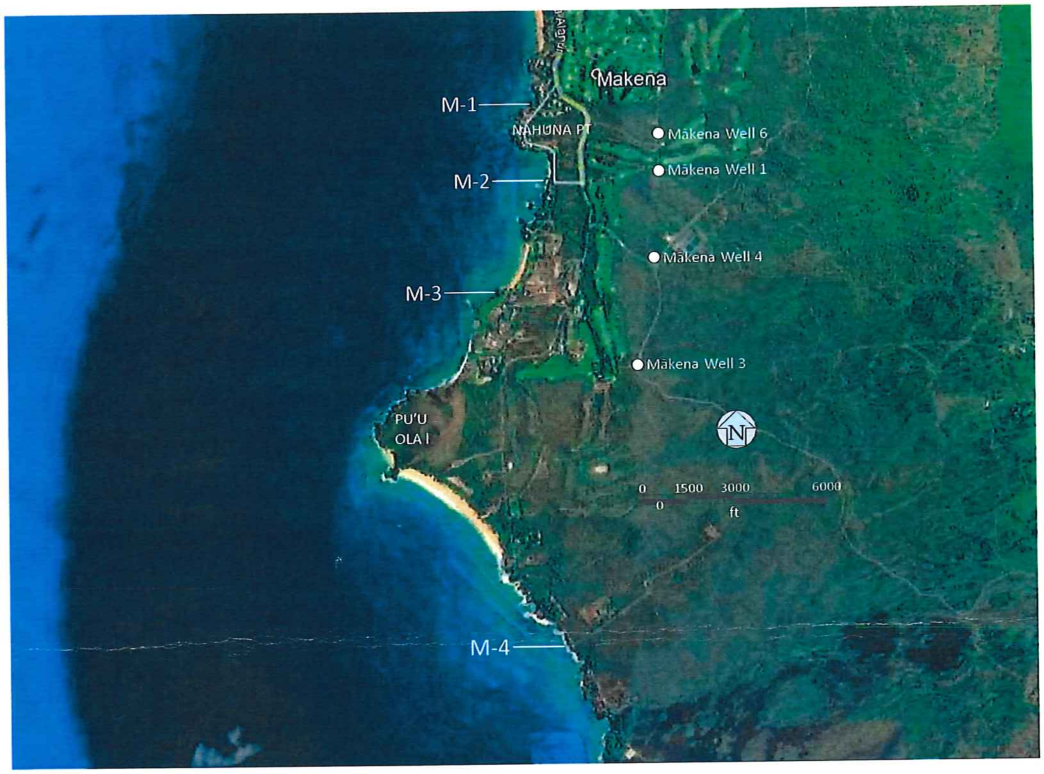

Figure 1. Location of water quality monitoring transects M-1, M-2. M-3, and M-4) and irrigation water supply wells at MG&BC.

Temperature, salinity, pH, and dissolved oxygen (DO) were measured *in situ* at each station. Collected water samples were immediately chilled and returned to the *AECOS* laboratory (*AECOS* Log No. 46025) for laboratory analyses. The following parameters were measured from these samples: salinity, turbidity, ammonium, nitrate+nitrite, total nitrogen (total N), ortho-phosphate, total phosphorus (total P), and chlorophyll α. Table 1 lists the instruments and analytical methods used for these field measurements and laboratory analyses.

The predicted tide on the September 1, 2022 event was high at 0708 hours (+1.38 ft), falling to a low of +0.62 ft at 1226 hours (Station 1615202, Mākena; NOAA, 2022). Winds were mild (1.6 to 2.6 mph) from the northeast to southeast and nearshore surf was minimal (0 to 1.0 ft). Water quality samples were collected at all stations along each of the four transects between 0800 and 0915 hours, followed by sampling at the MG&BC wells and storage pond.

Table 1. Analytical methods and instruments used for water quality analyses reported herein.

Analysis	Method	Reference	Instrument
Temperature	SM 2550B	SM (2017)	YSI Model 550 DO meter thermistor
Salinity	SM 120.1	SM (2017)	Accument AB200
pH	SM 4500H+	SM (2017)	pH pHep HANNA meter
Dissolved Oxygen	SM 4500-O G	SM (2017)	YSI Model 550 DO meter
Turbidity	EPA 180.1	USEPA (1993b)	Hach 2100Q Turbidimeter
Ammonium	EPA 349	USEPA (1997a)	Lachat Quickchem 8500
Nitrate + Nitrite	EPA 353.2	USEPA (1993a)	Lachat Quickchem 8500
Silicates	EPA 360.0	USEPA (1997c)	Lachat Quickchem 8500
Total Nitrogen	EPA 353.4	USEPA (1993a)	Shimadzu TNM-1
Ortho-Phosphate	EPA 365.5	USEPA (1997b)	Lachat Quickchem 8500
Total Phosphorus	EPA 365.5	USEPA (1997b)	Lachat Quickchem 8500
Chlorophyll α	SM-10200H(M)	SM (1998)	Turner Fluorometer

Results

Water quality results displayed in Tables 2 and 3 are compared with long-term historic mean values. On September 1, 2022, salinities were high compared to long-term means along all four transects. Salinity values did not increase with distance from shore as shown for historic values. Temperature values were high and consistent along Transects M-1 through M-3 due to late summer conditions. The lowest temperatures occurred along Transect M-4. pH means decreased from Transect M-1 to Transect M-4 and were reasonably close to historic means, except along Transect M-4. DO saturation means were low compared with historic means: the lowest values occurring at Transect M-3 and the highest at Transect M-1. Turbidity means were low along all four transects compared with historic means probably due to calm nearshore water conditions. Chlorophyll α mean values were also low at Transect M-1 through Transect M-3 compared with historic data.

Table 2. Physical/chemical water quality and chlorophyll α means for June 2018 through June 2022 (n = 17) compared to September 2022 results.

Transect	DFS† (m)	Salinity (ppt)		Temperature (° C)		pH		DO (% Sat.)		Turbidity‡ (NTU)		Chl. α‡ (µg/L)	
		Historic	Sept. 2022	Historic	Sept. 2022	Historic	Sept. 2022	Historic	Sept. 2022	Historic	Sept. 2022	Historic	Sept. 2022
M-1	2	34.01	35.10	26.6	27.1	8.17	8.23	102	98	*1.58*	1.78	*0.70*	0.44
	10	34.12	35.05	26.3	27.2	8.21	8.21	104	100	*0.92*	0.66	*0.50*	0.39
	50	34.26	35.07	26.3	27.1	8.21	8.18	100	93	*0.77*	0.50	*0.39*	0.20
	100	34.43	35.10	26.3	27.1	8.19	8.17	97	89	*0.50*	0.56	*0.28*	0.18
	Means	**34.20**	**35.08**	**26.4**	**27.1**	**8.19**	**8.20**	**101**	**95**	***0.94***	**0.88**	***0.47***	**0.30**
M-2	2	34.17	35.05	26.4	26.9	8.18	8.21	98	91	*2.02*	0.42	*0.42*	0.28
	10	34.17	35.19	26.4	27.2	8.19	8.20	95	91	*1.36*	0.63	*0.34*	0.26
	50	34.27	35.15	26.4	27.1	8.19	8.17	95	91	*0.86*	0.43	*0.28*	0.29
	100	34.47	35.13	26.4	27.3	8.18	8.18	95	89	*0.54*	0.24	*0.23*	0.22
	Means	**34.27**	**35.13**	**26.4**	**27.1**	**8.18**	**8.19**	**96**	**91**	***1.20***	**0.43**	***0.32***	**0.26**
M-3	2	34.02	35.15	26.4	26.9	8.18	8.11	105	88	*0.73*	1.42	*0.52*	0.38
	10	34.34	35.03	26.4	27.2	8.17	8.11	101	81	*0.57*	0.26	*0.38*	0.24
	50	34.53	35.18	26.4	27.2	8.17	8.15	99	88	*0.44*	0.26	*0.28*	0.25
	100	34.62	35.22	26.4	27.2	8.18	8.17	96	86	*0.41*	0.24	*0.22*	0.18
	Means	**34.38**	**35.15**	**26.4**	**27.1**	**8.18**	**8.14**	**100**	**86**	***0.54***	**0.55**	***0.35***	**0.26**
M-4	2	34.28	34.97	26.0	26.3	8.13	8.09	101	95	*1.21*	0.84	*0.56*	0.71
	10	34.33	35.10	26.0	26.4	8.14	8.08	100	94	*0.98*	1.05	*0.45*	0.45
	50	34.60	35.05	26.1	26.5	8.13	8.06	98	88	*0.63*	0.32	*0.30*	0.32
	100	34.72	35.15	26.1	26.6	8.08	7.92	95	84	*0.44*	0.36	*0.22*	0.24
	Means	**34.48**	**35.07**	**26.0**	**26.5**	**8.12**	**8.04**	**99**	**90**	***0.82***	**0.64**	***0.38***	**0.43**
Dry Standard		**+/- 10%**		**+/- 1C°**		**7.6-8.6**		**≥75%**		**≤0.20 NTU**		**≤0.15 µg/L**	

† distance from shore ‡ geometric mean *Values in italics exceed standard*

Table 3. Nutrient and silicates water quality geometric means for June 2018 through June 2022 (n = 17) compared to September 2022 results.

Mean nitrate+nitrite concentrations on September 1, 2022 (Table 3, above) were low along all four transects compared with historic means. There were no onshore-offshore gradients in nitrate+nitrite concentrations in September 2022, whereas historic data demonstrate a distinct reduction in nitrate+nitrite concentrations with distance from shore along all four transects. Ammonium means concentrations, on the other hand, were somewhat high along all four transects̄. The highest ammonium mean occurred at Transect M-4. Ammonium means showed no trend relative to distance from shore. Total nitrogen mean concentrations were low compared with historic means along all four transects. Ortho-phosphate means were slightly elevated compared with long-term means and decreased from a high mean along Transect M-1 to a low mean along Transect M-4. Total Phosphorus mean concentrations were low along Transects M-1 through Transect M-3 and somewhat elevated along Transect M-4 compared with historic means. Silicate mean concentrations were similar with historic means at Transects M-1 and M-2 and elevated at Transect M-3 and M-4.

Using the PacIOOS Regional Ocean Modeling System (ROMS) we can display approximated water current movements off the southwestern coast of East Maui that occurred just prior to and during our September 1, 2022 sampling event (Figure 2). Water flows were moving into the Mākena vicinity from the northwest before and during this sampling event.

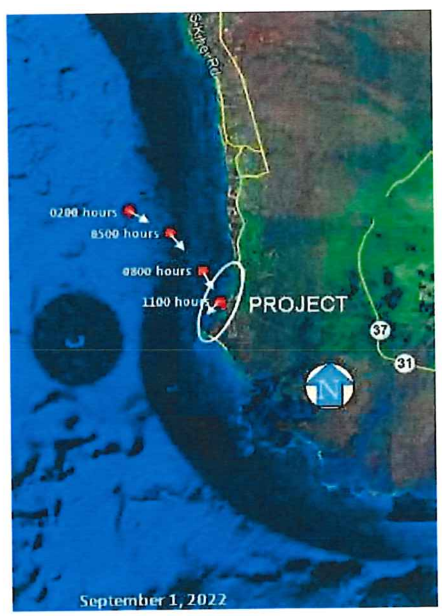

Figure 2. Approximated current flow off Mākena coast during morning hours (0200 to 1100 hours) of September 1, 2022 (PacIOOS, 2022).

Discussion

Salinities along nearshore stations (2-m distance from shore) on September 1, 2022 were elevated along all four transects; nitrate+nitrite concentrations were low along all four transects (Table 3). These conditions suggest that water flowing into the Makena area was from offshore and this is supported by the flow results in Figure 2 above. Nearshore ammonium concentrations are generated within these nearshore waters from natural biological processes. Ammonium subsidies are generally not related to groundwater seepage in Mākena nearshore waters. The elevated ortho-phosphate concentrations noted along all four transects on September 1 are not typical of elevated salinity values in Mākena nearshore waters and the source is unknown.

Tables 4 and 5 present estimates of groundwater nitrate+nitrite and ortho-phosphate subsidies in nearshore marine waters calculated for the September 1 sampling event. Indications of nitrate+nitrite subsidies were not apparent at any of the 2 m stations: nitrate+nitrite concentrations were low at all 2 m stations compared with historic data.

Table 4. Estimated nitrate+nitrite subsidies at nearshore (2-m) stations on September 1, 2022.

	Measured		Estimated	Subsidy
	NO_3+NO_2	Salinity	NO_3+NO_2	NO_3+NO_2
Location	(µgN/L)	(PSU)	(µgN/L)	(µgN/L)
Wells	1702	1.32	---	---
M-1	3	35.10	63	0
M-2	6	35.05	63	0
M-3	10	35.15	63	0
M-4	5	34.97	63	0
Standard Dev.†	173	0.06	---	---
Range†	1400-1980	1.20-1.44	---	---

† Standard Dev. and Range are for the well data mean.

Ortho-phosphate concentrations were elevated at all stations along all four transects compared with long-term means (Table 3). Ortho-phosphate concentrations from groundwater seepage into coastal waters would be associated only with low salinity values but occurred at elevated values along all four transects during this sampling event. Thus, the ortho-phosphate subsidies given in Table 5 can be presumed to be from a source other than Mākena groundwater seepage.

Table 5. Estimated ortho-phosphate subsidies at nearshore (2-m) stations on September 1, 2022.

Location	Measured		Estimated	Subsidy
	PO_4	Salinity	PO4	PO4
	(µgP/L)	(PSU)	(µgP/L)	(µgP/L)
Wells	60	1.32	---	---
M-1	4.0	35.10	2	2
M-2	5.0	35.05	2	3
M-3	4.0	35.15	2	2
M-4	5.0	34.97	2	3
Standard Dev.†	16	0.06	---	---
Range†	18-88	1.20-1.44	---	---

† Standard Dev. and Range are for the well data mean.

An estimate of the limiting nutrient (nitrogen or phosphorus) can be estimated by comparing molar ratios (N:P ratios) of dissolved inorganic nitrogen (DIN: nitrate, nitrite, and ammonium) to dissolved inorganic phosphate (DIP: ortho-phosphate). N:P ratios for 20 Hawaiian algal species range from 15:1 to 44.1 with an average of about 29:1 (Atkinson and Smith, 1983). High N:P ratios (>29.1) are potentially related to DIP limitation, whereas low N:P ratios (<29.1) are likely related to DIN limitation.

Analyses using accumulating data averages can be useful to decipher trends. Because we're still gathering data, sufficient nutrient and chlorophyll α data are not presently available to make statistical inferences regarding actual limiting nutrient determinations in Mākena waters. Data presented in Table 6 are based on our 17 historic sample sets and September 2022 sampling data and N vs. P limitation will vary from place to place along the coast and over time as additional monitoring results are added to the data set. For example, during the present sampling event, N:P values for monitoring stations along Transects M-1 through Transect M-3 were potentially DIN limited at all but one station (50 m station along Transect M-2) due to high DIP concentrations along these transects compared with DIN concentrations. Historically, however, DIP was typically limiting at most stations in Transects M-1 through M-3.

Since different algal species present a wide range of N:P requirements (Atkinson and Smith, 1983), constantly changing nutrient levels in these waters tend to prevent excessive algal growth by preventing favoring growth of just one or a few species.

Table 6. A summary of average DIN and DIP values for for June 2018 through June 2022 (n = 17) compared to September 2022 results.

Transect	DFS† (m)	DIP (µM/L)		DIN (µM/L)		DIN:DIP ratio		N/P Limited potential	
		Historic	Sept. 2022	Historic	Sept. 2022	Historic	Sept. 2022	Historic	Sept. 2022
M-1	2	0.09	0.13	4	0	49	3	P	N
	10	0.08	0.13	4	3	52	25	P	N
	50	0.08	0.13	3	1	41	5	P	N
	100	0.06	0.16	3	3	52	21	P	N
M-2	2	0.12	0.16	3	3	23	19	P	N
	10	0.11	0.13	3	2	24	12	P	N
	50	0.10	0.10	2	3	26	30	P	P
	100	0.08	0.13	2	2	28	17	P	N
M-3	2	0.11	0.13	4	4	35	28	P	N
	10	0.09	0.10	3	1	30	10	P	N
	50	0.08	0.13	3	4	39	27	P	N
	100	0.06	0.06	2	1	26	21	N	N
M-4	2	0.09	0.16	2	3	19	20	P	P
	10	0.09	0.03	2	6	28	188	P	N
	50	0.06	0.10	2	1	33	14	N	P
	100	0.06	0.10	2	4	27	42	P	N

† distance from shore

Conclusions

The September 1, 2022 monitoring event provided a different picture of water quality off MG&BC compared with most previous monitoring events. This difference was the somewhat rare occurrence of a mixture of salinities and elevated ortho-phosphate concentrations at all stations along each of the four transects and presumed related to the origin of the water mass from northwest of the Mākena area. As a result, DIN appeared to be the limiting nutrient at all stations along transects M-1 through M-3. Elevated ortho-phosphate concentrations along all four transects occurred at various salinities suggesting no influence from Mākena area groundwater input. Also evident is a lack of a decreasing silicate concentration gradient out from the shore.

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