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SUPPLEMENTAL EXPERT DISCLOSURE REPORT
Hawaii Wildlife Fund, et al. v. County of Maui, Civ. No. 12-00198 SOM BMK (D. Haw.)

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1. COMPLETE STATEMENT OF ALL OPINIONS THE WITNESS WILL EXPRESS AND THE BASIS AND REASONS FOR THEM

1-1. Summary of Opinions

This report has been prepared to present findings and opinions of my evaluation of the biological and chemical integrity of the coral reef environment located off of Kahekili Beach, West Maui. These opinions summarize scientific findings of studies conducted by myself and others to document the effects to the reef environment associated with discharge of tertiary treated sewage effluent from the Lahaina Wastewater Reclamation Facility (LWRF) that enters the ocean through localized "seeps" that have been identified near the shoreline of the Kahekili reef.

These opinions are based on results of the following scientific work:

1) field investigations that quantitatively document the physical and biotic structure of the reef off of Kahekili Beach,
2) a comprehensive analysis of chemical composition of the ocean water over the reef, and
3) examination of historical data collected by several governmental entities including Hawaii State Department of Health (HDOH), United States Geological

Survey, NOAA Coral Reef Ecosystem Division, and Hawaii State Department of Aquatic Resources.

In sum, it is my professional opinion that there is no existing sound scientific data or evidence to show that materials discharged in injection wells at the LWRF entering the ocean through nearshore submarine seeps have a detrimental effect on the structure and function of the Kahekili reef system, and have only a minimal effect on water quality in the immediate area of the seeps. The bases for this summary opinion are presented below.

I-2. The Lahaina Groundwater Tracer Study shows only that there is a hydrological connection from the LWRF to the ocean.

Results of the "Lahaina Groundwater Tracer Study –Lahaina Maui, Hawaii. Final Report (2013)(hereafter referred to as the "GTS") present data indicating that there is a hydrologic connection between the LWRF Injection Wells 3 and 4 and nearshore ocean waters. Fluorescein tracer dye added to LWRF injection Wells 3 and 4 was found to be flowing from two submarine springs areas termed the South Seep Group (SSG) and North Seep Group (NSG) located approximately 0.85 km (0.5 miles) to southwest of the treatment plant. Both seep groups were located in shallow water within 3 meters (m) (NSG) to 25 m (SSG) from shore. Although numerous, individual submarine springs in both the NSG and SSG are transitory in nature and small in size, averaging only about 2.5 centimeters (1 inch) in diameter. The combined total area of visible flowing submarine springs was calculated to be about 0.33 square meters (m^2) (3.6 ft^2) (this area can be envisioned as a square with each side about 23 inches long). The seeps sampled in the GTS are all within the shallow pavement zone of the reef which is a fossil reef bench. The NSG was located in a depression on the reef pavement close to shore that was often filled with deeply rippled beach sand.

While the GTS results indicate that groundwater, with a component of material from the LWRF, is discharging to the ocean from shallow nearshore submarine springs, it is important to understand that by definition, ALL groundwater flow has hydrologic connection to the ocean. Also by definition, injection wells ALL add materials to groundwater. Hence, all materials introduced into groundwater, including tertiary treated effluent via injection wells, reaches the ocean (with the exception of the component removed by metabolic processes within the flow path to the ocean).

1.3. Sewage discharge to the ocean is the standard method of disposal in Hawaii

Another point that appears to have become misinterpreted is the perception that the LWRF is unique in terms of discharging treated effluent to the ocean. With the exception of a relatively small amount of treated effluent that is re-used for irrigation and fertilization of non-consumptive land uses (primarily golf courses and landscaping), ALL treated sewage in Hawaii is discharged to the ocean through either injection wells or ocean outfalls. Treated effluent is discharged through ocean diffusers on the Islands of Oahu, Hawaii and Kauai. Several of these outfalls occur in shallow water in reef habitats. Exhibit 1 shows diffuser ports from the Hilo Wastewater Treatment Plant (top) and the East Honolulu Wastewater Treatment Plant (bottom). Each of these ocean outfalls consists of multiple ports at water depths of 35-40 feet. Clearly visible plumes of treated effluent can be seen discharging from these ports and rising in the water column.

What is also apparent is that there are live corals growing on the diffusers, there is no growth of macroalgae, and there is high clarity of the water indicating there are not high levels of plankton or suspended materials in the water. Ongoing NPDES mandated monitoring in the vicinity of the East Honolulu ocean outfall indicates that over the last 27 years the major effect to coral community structure in the area is the impact from periodic storm waves (Marine Research Consultants 2014). Hence, even when discharged from diffuser ports directly over coral reefs in a much more concentrated fashion than occurs at the diffuse submarine seeps off Kahekili, there is no apparent long-term impacts to coral reefs. Hence, there can be no *a priori* assertion that sewage discharge to the ocean results in negative impacts to benthic communities.

1-4. Inferred impacts from the seep discharge.

Thus, the overall finding of the GTS establishing a hydrologic connection between injection wells and the ocean is not surprising or unique. Nor is the occurrence of groundwater discharge at the shoreline unusual. In fact, all descriptions of the hydrologic system of the Islands of Hawaii include a zone of groundwater discharge near the shoreline where the water table meets the ocean. The normal hydrologic functioning of injection wells includes confinement of dispersing effluent below multiple strata with subsequent discharge to the ocean at depths beyond nearshore habitats. So while discharge of injectate to the ocean is the norm, it is unique to find occurrence of groundwater discharges adjacent to a shoreline that include materials emanating from deep injection wells. In addition, in what may be coincidence the region has also been the site of episodic nuisance algal blooms over the last several decades (although no blooms have been present for approximately the last 7 years). As a result, concerns with environmental consequences of seeps discharge goes far beyond the concept of a hydrologic connection between disposal on land and discharge through the sea floor.

1-5. Important, but Ignored, Principals of Physical Oceanography

It has been repeatedly asserted that the concentrations of physical and chemical constituents (e.g., nutrients, pH, temperature, salinity, dissolved oxygen) measured in groundwater from within the interior of the shallow pavement of the reef are the effective concentrations that affect biological processes in the surrounding coral reef habitats. This misconception ignores the multitude of mixing processes that occur in the water column following discharge out of the seeps. The effect of water column mixing is supported by water chemistry data presented in the GTS, as well as data reported by the HDOH who has conducted a water monitoring program at the seep sites from January 2012 to the present. While both of these data sets only include water column measurements from directly over the seeps, a sampling set consisting of a grid of sampling sites extending over the entire Kahekili reef and into open coastal waters that I conducted in August 2014 revealed that the effects of seep discharge were slightly elevated relative to GTS and HDOH data but were confined to a small area in the immediate vicinity of the seeps. No data indicates that the concentrations of water chemistry constituents measured within the interior of the reef represent the effective concentrations that can influence the coral reef community.

Virtually all physical, chemical and biotic processes in the ocean are mediated by an array of mixing of water masses along a wide gradient of temporal and spatial scales. Such mixing is driven by forces associated with differences in density (e.g., buoyancy), turbulence created by breaking waves, and horizontal forces such as wind shear, tides and current flows. All of these factors are in play in considering the effective concentrations of the physical-chemical constituents of the effluent discharge in the nearshore ocean.

With respect to density-driven mixing, it is well-established that the groundwater/effluent material is lower in salinity and higher in temperature than marine receiving waters. As a result, in the absence of horizontal turbulent mixing, upon discharge into the marine environment from the apertures that comprise the seeps, groundwater will immediately rise to the surface of the water column. On reaching the surface, the fresher warmer water will form a buoyant upper layer of lower density that contains dissolved concentrations of materials in the groundwater. If physical conditions through the water column are calm, the surface layer will spread in a lateral direction. Horizontal shear forces such as wind and tidal driven currents will transport the surface material laterally, but such forces will not mix the surface material in a downward direction back to the ocean floor. If turbulent forces are in effect, such as swells and breaking waves the surface material will be mixed downward within an area proportional in size to both the magnitude of the plume and the magnitude of the turbulent forces. For all cases, in order to evaluate effective concentrations of physico-chemical constituents at the sea floor where bottom dwelling organisms (i.e., coral reefs) occur, it is not appropriate to simply measure concentrations within the discharging seeps prior to any mixing processes and associate these concentrations with impacts.

1-4. Results of Analyses of Marine Water Chemistry Survey

1-4.1 Purpose

The inferred impacts to coral reef communities are the result of changes in marine water chemistry resulting from discharge of the portion of effluent from the LWRF that reaches the seeps in the shallow nearshore pavement zone of the reef. Thus, the first step in determining if impacts to the reef are plausible is to determine the extent of changes to water chemistry resulting from seep discharge.

1-4.2 Methods

In order to evaluate the effect of seep discharge on the chemistry of waters overlying the Kahekili reef, a field sampling program was carried out on August 23, 2014. Water samples were collected along nine transects that extended perpendicular to the shoreline. Eight sampling sites were established along each transect that extended from the highest wash of waves at the shoreline to a distance offshore deemed to be open coastal waters (~300 meters from shore). Exhibit 2 shows transect and sampling locations: Transect 3 bisects the location of the NSG while Transect 5 bisects the location of the SSG. At each sampling site, water samples were collected at the ocean surface, midway in the water column and just above the ocean floor. Site 1 on each transect consisted of a single sample collected at the highest wash of waves on the beach. Water samples were collected both by divers opening pre-rinsed bottles at the desired depth, and with a boat-mounted submersible pump capable of sampling to a depth of 33 meters (100 feet). The total program consisted of 198 samples collected at 72 sites. In addition to collection of discrete water samples, continuous profiles of temperature, salinity and dissolved oxygen were recorded *in-situ* at each sampling site (with the exception of beach sites 1 at each transect). All water samples were collected within a time interval of approximately 6 hours (0817-1420) so that temporal variability between locations was minimized.

Analyses were performed for the following chemical constituents specified in HDOH Water Quality Standards (WQS): ammonium nitrogen (NH_4^+), nitrate + nitrite nitrogen ($NO_3^- + NO_2^-$, hereafter referred to as NO_3^-), total nitrogen (TN), total phosphorus (TP), turbidity, chlorophyll *a*, (Chl a), pH, temperature, dissolved oxygen and salinity. In addition, while not listed in the HDOH water quality standards, orthophosphate phosphorus (PO_4^{-3}), dissolved silica (Si) and total suspended solids (TSS) are reported.

All samples were stored on ice following collection, and delivered to the analytical laboratory where they were processed within 24 hours of collection. All laboratory chemistry analyses were performed by Marine Analytical Services in Honolulu, HI (EPA Lab. No. HI00009). Marine Analytical Services possess "acceptable" ratings from EPA-compliant proficiency and quality control testing. The analytical laboratory has been performing chemical analyses for approximately 25 years, specializing in low-level seawater nutrient analyses. Analysis for inorganic nutrients (NH_4^+, PO_4^{-3}, NO_3^- and Si) were performed using a continuous flow Technicon Autoanalyzer according to published methods of seawater and wastewater analysis (Grasshoff 1983, Strickland and Parsons 1968, Technicon Industrial Systems 1973). TN and TP were analyzed in a similar fashion following alkaline oxidative digestion using potassium persulfate. Chl *a* was measured by filtering enough water through glass fiber filters for color to be visible; pigments on filters were extracted in 90% acetone in the dark at 20° C for 12-24 hours. Fluorescence before and after acidification of the extract was measured with a Turner Designs fluorometer. Salinity in the lab was determined using an AGE Model 2100 laboratory salinometer with a readability of 0.0001‰ (ppt). Turbidity was determined on 60 ml subsamples using a Monitek Model 21 nephelometer, and reported in nephelometric turbidity units (NTU). TSS was determined gravimetrically on filtered and dried samples using a Cahn electrobalance.

The EPA and Standard Methods (SM) methods that were employed for chemical analyses, as well as detection limits, are listed in the Code of Federal Regulations (CRF) Title 40, Chapter 1, Part 136, are as follows:

- NH_4^+ EPA 350.1, Rev. 2.0 or SM4500-NH3 G, detection limit 0.42 µg/L,
- $NO_3^- + NO_2^-$, EPA 353.2, Rev. 2.0 or SMSM4500-NO3, detection limit 0.56 µg/L,
- PO_4^{-3} EPA 365.1, Rev, 2.0 or SM4500-P F, detection limit 0.62 µg/L,
- TP EPA 365.1, Rev. 2.0 or SM4500-P E, detection limit 0.93 µg/L,
- TN SM 4500-N C., detection limit 1.4 µg/L,
- Si, SM 4500 SiO2 C, detection limit 7.0 µg/L.
- Chlorophyll a, SM 10200, detection limit 0.001 µg/L
- pH, EPA SM4500H+B, detection limit 0.001 pH units
- Turbidity, EPA 180.1, Rev. 2.0 or SM2130 B, detection limit 0.01 ntu
- Temperature, SM 2550 B, detection limit 0.01 degrees centigrade
- Salinity, SM 2520, detection limit 0.00 3ppt
- Dissolved Oxygen, SM4500 O G, detection limit 0.01% sat.
- Total Suspended Solids, SM 2540D, detection limit 0.1 mg/L.

1-4.3 Results

Exhibits 3 and 4 are tables showing results of all water chemistry analyses for the 198 samples collected over the Kahekili Reef, along with depth, distance from shore and geographic coordinates. Exhibits 5-9 are three-dimensional histograms showing the concentration of dissolved inorganic nutrients and salinity at each sampling site at each transect.

Several major trends are evident in the data. On all nine transects there are horizontal gradients of decreasing concentrations of silica (Si), nitrate + nitrite nitrogen ($NO_3^- + NO_2^-$), and phosphate phosphorus (PO_4^{3-}) with distance from shore. Correspondingly, there are increasing values of salinity with distance from shore. Thus, the highest concentrations of PO_4^{3-}, NO_3^- and Si and the lowest salinities occur at the shoreline grade steadily with distance from shore. These gradients are most prominent on Transects 3 and 5, located at the NSG and SSG, respectively. Gradients are least pronounced on Transects 1 and 9 located farthest from the seeps (Exhibits 5-9).

The pattern of decreasing concentrations of inorganic nutrients (Si, PO_4^{3-}, and NO_3^-) and increasing salinity with increasing distance from shore represents the typical situation for Hawaiian shorelines where groundwater flowing from land enters the ocean (Ex. Dollar and Atkinson 1992, Knee et al 2010). Naturally occurring groundwater contains substantially higher concentrations of Si, PO_4^{3-} and NO_3^- compared to ocean water, and has a salinity of essentially zero compared to a salt content of approximately 3.5% (35 parts per thousand or ‰) in ocean water. Following discharge at the shoreline, a narrow zone occurs where groundwater mixes with ocean water. The extent of the mixing zone is proportional to both the magnitude of groundwater discharge and the intensity of physical mixing processes (primarily wave energy) in the nearshore region.

The August 2014 survey was conducted during a period of small surf and relatively light winds for the West Maui area, which along with a low tide resulted in minimal mixing conditions in the nearshore area. With such conditions, gradients from the shoreline to offshore ocean are evident on all transects indicating detectable groundwater input at the shoreline. The presence of distinct horizontal gradients at all sampling locations verifies groundwater input is the typical situation at the Kahekili region. The peaks in concentrations of Si and NO_3^- at Transects 3 and 5, located at the sites of the NSG and SSG, respectively, indicate that the seep discharge is contributing to the concentration of these nutrients in the water column to a greater extent than at other locations along the sampling regime.

It is clearly evident in the 3-D plots (Exhibits 5-8) that the concentrations of Si, NO_3^-, PO_4^{3-} are highest and salinity lowest along the shoreline at all transects, and peak at transects 3 and 5. It is also evident that elevated concentrations of nutrients extend farther seaward on transects 3 and 5. On transects 3 and 5 elevated levels of dissolved N and P in bottom waters extended 20 m (66 feet) from shore, which is over the reef pavement zone, and not over the aggregate reef zone. It is also evident in Exhibits 3-8 that peak concentrations of dissolved inorganic nutrients occur just above the sea floor over the seeps on Transects 3 and 5. At the ocean surface directly over the seeps, concentrations are substantially reduced. Hence, even though the water discharging from the seeps is far less saline than ocean water causing it to rise in the water column, mixing processes occurring in the shallow water column are dilute seep discharge.

Contrary to Si, PO_4^{3-}, and $NO_3^{-,}$ concentrations of ammonium (NH_4^+) showed no consistent pattern with respect to distance offshore or among the transects (Exhibit 9). As NH_4^+ is not generally found in elevated concentration in groundwater relative to coastal ocean water, the lack of distinct gradients indicates that there is no source of NH_4^+ to the ocean from land. The lack of elevated concentrations of NH_4^+ in the nearshore areas of Transects 3 and 5 indicate that discharge from the seeps is not a significant contributing factor to concentrations of NH_4^+ in the ocean.

Concentrations of Chl *a* and turbidity were consistently highest near the shoreline and decreased with distance offshore on all nine transects (Exhibit 3). Values of Chl *a* and turbidity were slightly elevated over the SSG, but not over the NSG. While there is a slight trend of increasing pH with distance from shore, there is no evidence of anomalous values at either of the seep sites. Similarly, there is no evidence of any gradients of increasing or decreasing concentrations of Total

Organic Nitrogen (TON) or Total Organic Phosphorus (TOP) along any of the transects, and no change in concentration in the vicinity of either of the seep groups (Exhibits 3 and 4).

Exhibits 10 and 11 show vertical profiles of salinity and temperature at each of the survey sites on each of the transects (with the exception of site 1 located in the wave surge zone). Several trends are evident in these profiles. With respect to salinity (Exhibit 10) there are distinct layers of low salinity water in the upper 0.25 m of the water column on transects 2, 3, 6, 7 and 8. These layers likely represent input of low salinity groundwater at the shoreline that is maintained as a surface layer up to several hundred meters from shore. On transects 3 and 5, located at the NSG and SSG, respectively, it can be seen that salinity through the entire water column at sites 2 (NSG) and 3 (SSG) are depressed slightly below 34‰. At a depth of between 1 and 1.25 m at the SSG, there is a further depression of salinity to about 33.1%. These depressions of less than 2‰ directly over the seeps represent the only substantial variation of salinity over the entire reef tract (note that the USGS (2012) survey found a nearly identical depression of salinity in the vicinity of the seeps). With the exception of a small depression of salinity at the bottom at site 1 of transect 4, there is no evidence of depressed salinity at the surface of the reef that could be attributed to discharge of seep water through the reef surface.

Vertical profiles of temperature (Exhibit 11) reveal generally consistent temperatures throughout the water column within a range of about 26.6 -27.0° C. Many of the profiles displayed a thin layer of lower temperature in the upper 0.10 m of the water column. As the magnitude of the cooler layers do not correspond to distance from shore, it is not likely that they reflect input of groundwater mixing with ocean water. Rather, they likely represent the effects of evaporative cooling of the surface by the moderate winds that occurred during the period of sampling. There is no evidence in these vertical profiles of elevated water temperature at the sampling sites directly over the seeps, or just above the reef surface.

It is important to note that with the exception of some of the thin surface layers of cooler water attributable to evaporative cooling, virtually all of the recorded temperatures over the reef at depths greater than one meter are above 26.5°C. The temperature of the "anomalously warm buoyant fluid emerging from the seeps" used in the GTS "Aerial Infrared Sea Surface Temperature Mapping" was 26.5°C. Hence, the ambient temperature throughout the reef in August 2014 was equal to or higher than the supposed elevated temperature anomalies from the seep discharge. With natural conditions exceeding the temperature anomalies from the seep, any alleged effect of the seeps in terms of water temperature can be disregarded.

A well-documented method to evaluate the source of nutrient input to estuaries and the ocean involves scaling the nutrient concentration to salinity (Dollar and Atkinson 1992, Officer 1979, Smith and Atkinson 1993). Exhibit 12 shows concentrations of dissolved silica (top) and nitrate nitrogen (bottom) plotted versus salinity for each sample collected along the nine transects off Kahekili Beach. It can be seen in the plot of silica that all data points fall on a single straight line with no curvature. The linearity of the data points indicate that water samples from all transects consist of a mixture of groundwater of similar composition and ocean water.

The straight blue lines in each plot are the conservative mixing line constructed from joining the endpoint concentrations of sewage effluent sampled from the LWRF and open coastal water. The solid blue line is from Dollar and Andrews (1997), while the dashed blue line is from the GTS. The straight red line is the mixing line constructed by connecting the endpoint concentration of water from "production wells" in the West Maui area (data from the GTS). It is assumed that the production well is supplying potable water from a location above any source of anthropogenic input. The green line represents the endpoint concentration from well located close to the shoreline. The solid green line is from Soicher and

Peterson (1997) while the dashed green line is a “monitoring well” reported in the GTS. The similarity of the slope of all three mixing lines indicates that all are from the same groundwater source, and that the concentration of Si in sewage is not appreciably altered from that in groundwater. The similarity of the sample data line and the conservative mixing lines indicates that the source of Si in ocean samples at all sampling sites originates as a single groundwater source.

Data points in the plot of concentrations of NO_3^- versus salinity also prescribe a single straight line nearly as uniform as the Si data line (Exhibit 12). The only location where data points do not fall on the line are from transect 2. The wide disparity in the slope of the mixing lines, however, indicates that the concentration of nitrate in groundwater is affected by land use; the steepest slope occurs with the sewage mixing lines, followed by the lower slope of the loe elevation well groundwaters, followed by lowest slope of the upslope groundwater mixing line. It is of interest to note that there is are substantial differences in the slope of both the sewage and low elevation groundwater sampled in 1997 and 2012. It appears that both the sewage effluent and groundwater from near the shoreline contain less NO_3^- in 2012 relative to 1997.

The uniformity of the linear data points indicates that the concentration of NO_3^- in groundwater mixing with ocean water is of very similar composition at all transect locations, including the seep sites (Transects 3 and 5). The location of the majority of data points between the production well and monitoring well mixing lines indicates that the composition of groundwater entering the ocean at all sampling sites is not appreciably different than what would be expected with no influence of any other sources of NO_3^-. Thus, while there may be more groundwater entering the ocean at the seep sites owing to concentrated output through the seep apertures, the composition of the seep water is not substantially different in composition (with respect to NO_3^-) than at the other transect locations. The location of the data points relative to the mixing lines indicates that the origin of the groundwater entering the ocean is more similar to typical groundwater rather than sewage effluent. The lack of differentiation in slope of data points collected directly over the seeps from other areas located at a distance from the seeps indicates that there is not a significant contribution of sewage material to the nearshore ocean from the seep discharge.

In summary, while this data set represents only a single intensive sampling event in August 2014, the results reveal the major factors affecting water quality in the Kahekili area. These data provide evidence of groundwater discharge at the shoreline of all survey sites. The highest values of chemical constituents associated with groundwater discharge occurred at the two areas where the submarine seep discharge occurs. But the data do not reveal a distinct signal representative of the sewage effluent that is different at the seeps than at other areas along the shoreline.

No other water quality constituents showed substantial variability that could be attributed to the submarine seeps. Thus, while the GTS revealed indications of dye within the shallow pavement zone, it did not include a comprehensive or wide-spread sampling program to determine the effects of seep discharge throughout all zones of the reef (with the exception of temperature in the upper 1 mm of the water column). The present data set, which did indeed define the distribution of nutrients and other chemical constituents across the various reef zones throughout the water column shows little or no effect of the effluent discharge on water chemistry.

1-5. Comparison of water chemistry data

It is of value to compare the nutrient concentrations measured in August 2014 at the seep sites to other data sets in order to determine if this sampling was representative of typical conditions on the Kahekili reef. Exhibit 13 is a summary table of water chemistry data collected by the Hawaii Department of Health (HDOH) at the Kahekili seeps from January 2012 to December 2014. These data include groundwater samples collected from within reef rock (termed "Seep", as well as samples from the mid-point and surface of the water column directly over the seeps.

Dissolved inorganic nitrogen (DIN) consists of nitrate-nitrite nitrogen ($NO_3^-+NO_2^-$) plus ammonium nitrogen (NH_4^+), while dissolved inorganic phosphorus is another term for phosphate phosphorus (PO_4^{3-}). DIN and DIP are the forms of nitrogen and phosphorus taken up by plants. Peak values of DIN measured in August 2014 directly over the NSG and SSG ranged from about 3 µM (42 µg/L) to 10.8 µM (151 µg/L). In comparison, the geometric mean values of DIN measured at the surface during the HDOH long-term monitoring directly over the NSG is 1.3 µM (19 µg/L) and 1.1 µM (16 µg/L) over the SSG. While DIP is not measured in the HDOH data set, the geometric mean concentrations of Total Phosphorus (TP) are 0.73 µM (23 µg/L) at the NSG and 0.67 µM (21 µg/L) at the SSG. Values of TP over the seeps in August 2014 were 0.6 µM (19 µg/L) and 1.2 µM (37 µg/L). Hence, the nutrient values measured over the seeps in the August 2014 survey are up to about 8 times higher for DIN, and 2 times higher for TP than the average values of the long-term data set collected by the HDOH

Measurements of DIN in coastal water reported in the GTS at the SSG and NSG ranged from 0.38-0.81 µM (5.3-11.3 µg/L) and DIP ranges of 0.16-0.44 µM (5.0-13.6 µg/L (p. ES-11 Final Report). These ranges for DIN are about 10 times less than measured over the seeps during the August 2014 study, while DIP values are about the same in both studies. As the single sampling event in August 2014 produced results showing higher values of nutrients in the water column over the seeps than the geometric means of the HDOH data set or values reported in the GTS, the August 2014 data captured the effect of seep discharge on water quality.

It is also important to put the concentrations of nutrients measured at Kahekili by both the HDOH monitoring and GTS in context with measurements from other sites in West Maui. The HDOH program collects control samples at Wahikuli (downslope from a community that is not connected to the County sewer system but rather relies on individual residential cesspools) and Black Rock (offshore of the Kaanapali Resort and Golf Courses). Geometric means of DIN at Wahikuli and Black Rock were 5.5 µM (77 µg/L) and 217 µM (3049 µg/L), respectively (Exhibit 13). Hence, the values at Wahikuli and Black Rock ranged from 4 to 150 times <u>higher</u> than measured in water directly over the seeps.

Hanakao'o Beach served as a control site in the GTS. DIN concentrations at this site were 7.7 µM (108 µg/L), or about 10 times <u>higher</u> than over the seep clusters. DIP at Hanakao'o Beach was about twice the concentration in water directly over the seeps.

The 2014 STATE OF HAWAII WATER QUALITY MONITORING AND ASSESSMENT REPORT: Integrated Report to the U.S. Environmental Protection Agency and the U.S. Congress Pursuant to §303(d) and §305(b), Clean Water Act (P.L.97-117), approved October 2014 by the EPA, shows areas that are "delisted" from the list of impaired waters based on attainment of water quality standards (Section B.3.1). On Maui, Kahekili Beach was delisted for NO_3^-+NO_2^- and NH_4^+ based on assessment of data indicating that applicable WQS are being attained resulting in a category change from 5 (available data indicates that at least one designated use is not being supported or is threatened and a TMDL is needed) to 2 (available data indicate that some but not all designated uses are supported). Attainment of WQS for TN and TP at Kahekili were attained prior to 2014 (Exhibit 14). As DIN (NO_3^-+NO_2^- and NH_4^+), TN and TP are the nutrients found in elevated concentrations in sewage, the delisting of all of these constituents from the Kahekili area indicates that there is not likely a significant, or even detectable effect of the seep discharge on the overall quality of marine waters. In fact, Kahekili is the only monitoring site on Maui that is not impaired for all nutrients.

1-6. Effects of nutrients on reef corals

The effect of elevated nutrients on corals is often cited as a major concern regarding the impact of the seeps on reef community structure. Thus, It is important to assess the potential effects of nutrient subsidies on reef corals based on existing scientific literature.

Kinsey (1991) observed that it is incorrect to jump from the observation that coral reefs can do well under low nutrient conditions to the conclusion that coral reefs require such low nutrient environments. Smith and Buddemeier (1992) agree with this, noting some reefs look healthy and are apparently doing well in a milieu of naturally high nutrient levels. These authors also note that while is no evidence that increased nutrients are a physiological stress at the organism level, changes in coral community structure can occur as a secondary effect when rapidly growing phytoplankton and benthic algae can gain a competitive advantage over corals. Atkinson and Falter (2003) state that "nutrient loading and its subsequent impact is one of the more important issues concerning conservation and protection of coral reefs. It is widely believed that any nutrient input to coral reefs is deleterious. This conclusion, that nutrients are deleterious to a reef ecosystem, is simply incorrect."

To illustrate, water in tanks growing corals at the Waikiki Aquarium comes from saline groundwater wells, and has a DIN concentration of ~7 µM (98 µg/L) (Atkinson et al. 1995). Growth rates of corals in tanks at the Waikiki Aquarium were been measured to be near the upper rates reported from any natural reefs, demonstrating corals can and do flourish in relatively high-nutrient water. With a single exception all values of DIN measured over the Kahekili reef were below the values of 7 µM measured in Waikiki Aquarium water where corals grow at maximum rates with no detrimental effects.

The most ambitious field experiment to investigate the effects of nutrient enrichment on a number of coral reef processes was the ENCORE (Elevated Nutrient on Coral Reef Experiment) project on the Great Barrier Reef (Koop et al. 2001). Experimental loading of nutrients to the reefs was increased from 10 μM ammonium and 2 μM phosphate to 20 μM ammonium and 4 μM phosphate in the second year of the study because of the lack of any effects at the original level of nutrient enrichment. Even at the increased levels "impacts were generally sub-lethal and subtle, and the treated reefs at the end of the experiment were visually similar to control reefs." Hence, the highest measured value of elevated nutrients found at the Kahekili site directly over the SSG was about half the concentration that produced no effects to corals in the ENCORE experiment. The average value of nutrients over the Kahekili reef is far below any values in the existing scientific literature that could be interpreted to be detrimental to coral growth. In addition to nutrients, none of the other chemical or physical parameters measured over the Kahekili reef were near any thresholds of impact to coral reef organisms.

Szmant (2002) also feels support for the claim that nutrient over-enrichment is considered a major cause of degraded reefs by promoting shifts from high coral cover to high cover and biomass of fleshy algae are equivocal at best. While the ENCORE experiment showed that nutrient enrichment is not the sole or major cause of shifts in coral coral/algal abundance, Szmant indicates that other factors, particularly reduction in grazing or stress associated with changes in water properties (i.e., thermal stress) are required to contribute to an imbalance that can lead to shifts in community structure.

Field investigation of water chemistry over the entire Kahekili reef indicated the presence of dissolved nutrients from groundwater discharge along the entire shoreline composing the study area. While groundwater nutrient discharge was highest in the shoreline area where the seeps are located, the resulting concentrations directly over the seeps were not of a sufficient magnitude to negatively affect coral reef structure and function. When mixing processes are considered that are required to transport the discharge to the zones of the reef where corals occur, nutrient concentrations will be reduced even further. In addition, applying the data to a simple mixing model which scales nutrient concentrations to salinity, it is apparent that material emanating from the seeps is not significantly different in composition than groundwater entering the ocean all along the Kahekili coastline.

While there may be some contribution of the LWRF effluent to the seep discharge, it appears to be largely masked by the discharge of typical groundwater. It is also important to note that my water sampling protocol is the only one to date that uniformly measured constituents in a structured way across the entire Kahekili reef, rather than just at a single geographical location above the seeps.

1-7. Coral Reefs Community Structure Analysis

1-7.1 Background

Coral reefs are shallow-water, tropical or subtropical marine ecosystems that contain one or more communities composed primarily of organisms capable of building a lasting non-living structural framework composed of limestone. Communities of framework-building organisms have persisted or recurred over a sufficiently long period to have built a three-dimensional structure on top of the underlying (non-reef) bedrock. The most conspicuous organisms in reef formation are scleractinian corals, which are defined as corals with high calcification rates that produce most of the calcium carbonate (limestone) that makes up the reef framework. Other important reef calcifiers are various calcareous algae: crustose red coralline algae cement the softer, more porous coral skeletons, creating a more wave-resistant structure. The association of these organisms produces a living structure that grows and maintains itself near sea level.

Because coral and algae are responsible for reef construction and maintenance, their environmental limits determine the distribution of reefs throughout the world's oceans. The physical and chemical parameters most affecting the distributions of coral and algae are temperature, light, salinity, nutrients, carbonate saturation state and water motion, while the most important biotic parameter is likely grazing. The specific influences of these parameters on reef-building organisms are interconnected and complex, and they are a major focus of ongoing reef research, particularly with respect to the influence of human-induced changes to environmental conditions, as well as fishing pressure.

Most Hawai‘i reefs are located on island slopes near deep oceanic waters with high wave energy that flushes sediment and pollutants from the system while moderating temperature. Hawai‘i is relatively free of industrial development, mining and other highly polluting activities, although sediment impact resulting from improper land use practices and feral ungulates is a localized problem. Although over half of all reefs in the wider Pacific region are currently listed as threatened by the World Resources Institute, Hawai‘i has one of the lowest overall threat ratings (Burke et al. 2011). The main Hawaiian Islands occupy a unique geographic position in an area of the north-central Pacific that has escaped most major bleaching events as well as rapid sea level rise over the past decade.

Hawaii reefs also are unique in that they occur near the northern geographic limit of coral occurrence, and are essentially upstream of the centers of coral evolution and biodiversity in the Indo-Pacific. As a result, species richness of Hawaiian reefs is considered low by global standards with only 50-60 species in total, and only 5 species that contribute significantly to reef building.

It has been well-documented that wave forces are the most important factor in shaping the geologic and biotic composition of open coastal reefs in Hawaii (Dollar 1981, Grigg 1983, 1998, Fletcher et al. 2008). While coral reefs are often perceived as fragile, relatively stable ecosystems whose community structure is dictated primarily by biotic interactions (i.e., competition between coral species), such is not the case in most Hawaiian reef settings. Reef communities have been described as "temporally varying mosaics." This term describes the constantly changing patchwork of reef communities that are in different stages of recovery from various sources of disturbance. Therefore, reef ecosystems can be considered somewhat unstable or even unpredictable, with changing composition considered more typical than constancy. In this view, the norm for reefs, particularly reefs in Hawaii, is suggested to be one of continual stages of self-replacement and recovery from various levels and types of natural disturbances.

Grigg and Maragos (1974) were the first to apply the concept of the "intermediate disturbance hypothesis" to Hawaiian coral reefs. By this theory, physical disturbance is the key factor in the reef successional process, particularly in terms of diversity, which is often equated with ecosystem robustness and stability. While catastrophic disturbances can be severe enough to effectively remove the living components of an existing reef and set the successional clock back to zero, "intermediate" disturbances can result in maintenance of elevated diversity and overall community stability by preventing succession to reach climax stages. The applicability of these concepts of temporal and spatial mosaics driven by intermediate disturbances to the Kahekili reef is discussed below.

1-7.2 Reef Zonation

All coral reefs display some form of spatial variation in composition as a result of differential exposure to environmental factors. As stated by Blanchon (2011) "Shallow coral assemblages show a distinct zonation as wave energy and hydrodynamic disturbance varies with depth and margin exposure." All open coastal coral reefs in Hawaii follow to some extent a well-documented consistent zonation pattern in response to physical environmental factors (Dollar 1981, Dollar and Tribble 1992, Grigg 1983, 1998, Fletcher et al. 2008). To ignore the presence of distinct zoned habitat structure and assume that reefs in Hawaii exist as uniform physical and biotic assemblages from the shoreline to the outer limit of reef growth shows a disregard for the most basic concept in reef ecology.

The generalized open coastal fringing reef typology in Hawaii consists of a nearshore barren ledge or pavement that is often the subtidal extension of the interface between land and the ocean. As this area is generally subjected to the most severe environmental conditions of wave impact, shifting sand, and exposure to the atmosphere, coral colonization is absent or greatly restricted. These shallow nearshore platforms consist of calcium carbonate structures that were accreted by reef building organisms during previous higher stands of sea level. Cores drilled through an area of the reef flat at Hanauma Bay comparable to the reef flat at Kahekili revealed that the youngest reef material present today was approximately 2,000 to 3,000 years old, suggesting that sea level receded to its present level at this time and prevented the growth of younger material (Easton and Olson 1976, Grigg 1998). During the intervening millennia these shallow nearshore platforms have been weathered by wave forces, chemical dissolution and bioerosion to form the pitted and irregular pavement that exists at present. Hence, owing to lack of limestone accretion, the shallow reef pavement cannot be considered a growing reef.

Part of the survey work for the Kahekili Herbivore Fishery Management Area conducted by the Coral Reef Ecosystem Division/Dept. of Aquatic Resources (CRED/DAR)(Walsh et al. 2010) consisted of developing a habitat classification scheme for the area. The habitat designation for the nearshore non-living limestone bench for this work is “Shallow Pavement.” The CRED/DAR description of the nearshore habitat at Kahekili is “largely flat, low relief and low coral cover areas dominated by limestone pavement and loose sediment (sand) with a depth range of 4-8 feet.”

Seaward of the shallow pavement, physical forces associated with wave impacts are reduced, and conditions become tolerable for coral settlement and growth.

The typical Hawaiian reef zone that begins adjacent to the nearshore pavement forms a fringing band consisting of corals growing on a limestone foundation. The habitat designation for this fringing reef fronting Kahekili Beach used by CRED/DAR is "Shallow Aggregate Reef." The CRED/DAR definition of this zone is "substrate largely dominated by corals with patches of sand, and moderate or high physical complexity, with a depth range of 5-23 feet." The inner area of the shallow aggregate reef at Kahekili is gently sloping and is colonized by the greatest diversity of corals, although the dominant species is typically *Porites lobata.* This species is the most common coral throughout Hawaiian reefs, and most often occurs as large dome-shaped colonies that can reach sizes of up to several meters in diameter. At the outer regions of the shallow aggregate reef, bottom slope increases, forming the reef slope, and the dominant corals are interconnected mats of *Porites compressa*, commonly called finger coral.

While the coral reef in the area of the seeps at Kahekili Beach follows the typical Hawaiian pattern of reef zonation, it is somewhat unique in that the entire zonation pattern is compressed into a relatively narrow area spanning a distance of only approximately 150 m from the shoreline to the outer limit of coral occurrence. Exhibits 15 and 16 are sections of a Google Earth image of the Kakekili reef acquired on January 12, 2013. This image is unusual in that it was acquired at a time when water clarity was high and wave action low. As a result, it is possible to clearly distinguish the differentiation of bottom structure which defines the zonation pattern. The zonation scheme is clearly visible as: 1) the extension of the sand shoreline to the intertidal area; 2) the nearshore shallow pavement, and 3) the inner and outer shallow aggregate reef. The differentiation in texture between all of these zones is clearly defined, particularly between the inner and outer aggregate reef. The numerous circular objects visible throughout the inner reef zone are individual colonies of coral, primarily large heads of *Porites lobata*. The smoother texture of the outer reef zone are primarily contiguous mats of *Porites compressa*. Photographs to illustrate the appearance of each of the reef zones and the seep groups are shown in Exhibits 17-21.

1-7.3 Algae

In addition to corals, marine organisms termed algae occur in three functional groups on most reefs: turf algae, crustose coralline algae (CCA), and the larger macroalgae. Each of these major groupings contains hundreds of species worldwide and each group is unique and important in its own way. All three groups are usually present on just about any reef, and their relative abundances can be a good indicator of the health of the reef.

Turf algae consist of a multi-species assemblage of diminutive, often filamentous, algae that attain a canopy height of only 1 to 10 mm (less than ½ inch) forming mats on rock and dead coral. Turf algae are the first to colonize vacant reef surfaces and cover essentially every non-living hard surface on a reef not covered by something else. As such, they are frequently the dominant algal constituents in shallow coral reef ecosystems. Algal turf contributes up to 80% of coral reef primary productivity, making it a major food source for animals on the reef, and is the primary food source for many reef grazers.

CCA are heavily calcified species that, like the corals, contribute to the growth and development of the reef structure. When alive and thriving, they generally look like pink rock. Some species of CCA are also important for their role in the recruitment and settling of the larvae of corals and other invertebrates, a necessary step for on-going colonization of the bottom. Relatively fast-growing CCA act as glue on reefs, cementing loose components of a reef system together, and serve as a settling surface for larval invertebrates and other algae. Without CCA holding everything together, much of a reef would be washed into deep water or onto shore during heavy storms.

Marine macroalgae, or seaweeds, are plant-like organisms without roots or leaves that generally live attached to rock or other hard substrata in coastal areas. Macroalgae are a group of large fleshy and/or calcified species that span a wide range of growth forms and are divided among three large groups that are named according to the color of their dominant photosynthetic and accessory pigments: red (*Rhodophyta*), green (*Chlorophyta*) and brown (*Phaephyta*). Macroalgae have important ecological and economic roles on coral reefs. They are primary producers that form the basis of many marine food chains and provide habitat and refuge for a range of organisms. They are also commercially important for food (e.g. sushi), science (e.g. agar culture mediums) and for their compounds (e.g. alginate - used in a variety of products from toothpaste to ice cream). Macroalgae are also often used as indicators of water quality and reef health. The abundance of macroalgae responds to changes in nutrient concentrations, with increased abundances often indicating elevated levels of nutrients.

Although macroalgae can be more resilient to physical and biological disturbances than coralline and turf algae, grazing by certain herbivores and high wave energy can inhibit macroalgal growth. Macroalgae can also be major contributors to reef degradation via ecological ‘phase-shifts’ whereby the dominant taxa on the coral reef shifts from hard, reef-building corals to fleshy macroalgae. The phase shift is generally initiated by a disturbance such as coral bleaching, outbreaks of the coral-eating crown-of-thorns starfish (COTS), coral disease or storm damage. When the disturbance is removed from a healthy system, algal abundance will diminish, and corals will recover and recolonize the disturbed area. If, however, the number of herbivores in the area has been reduced by overfishing, or the area is affected by elevated levels of nutrients or sediment, a permanent shift to an algal dominated system and an overall reduction in the aesthetic value of coral reefs might occur.

The Plaintiff’s expert, Dr. Jennifer Smith, now focuses on the occurrence of “turf algae” or “fleshy turf algae” instead of fleshy macroalgae as she did earlier in the case for alleged reef impacts associated with the seeps. This is likely because her survey of the Kahekili reef in 2014 confirmed what I have been saying: there is very little fleshed algae on the reef at the present time. The term "fleshy turf algae" is somewhat of an oxymoron, and is not commonly applied in reef studies. The use of "fleshy" inaccurately suggests that the turf at Kahekili consists of thick and dense plant material, which is clearly not the case. In fact, the habitat term used in the CRED/DAR surveys at Kahekili that describes this type of bottom cover is "turf/bare." This habitat classification indicates that while there may be a covering of short algal turf, the substratum can also appear bare of any living cover. The mere presence of turf algae does not indicate declining reef condition. To the contrary, the scientific literature is perfectly clear that turf algae is a normal, common and fundamentally important component of the reef ecosystem. As stated by Fong and Paul (2011) "Algal turfs are ubiquitous across reef zones" as well as "Algal turfs are also ubiquitous on hard substrates throughout tropical reef ecosystems." While turfs are often dominated by filamentous members of the Rhodophyta, they also can include filamentous green algae and cyanobacteria, and cropped bases of larger algae. In contrast to crusts, turfs are characterized by extremely high rates of primary productivity, though biomass is usually very low (<0.27 kg m^{-2}), suggesting an opportunistic life-history strategy where success is a result of growing slightly faster than herbivores can consume them (Fong and Paul 2011).

The CRED/DAR benthic cover classification scheme delineate turf algae as the classification of "turf-bare". This category includes "numerous species from multiple evolutionary groups (red algae, green algae, brown algae, and cyanobacteria). These types of mixed algal assemblages are typically short in stature (< 2 cm in height), and often contain filamentous algae (hair-like morphologies) as opposed to fleshy algae (thick branched or sheet-like morphologies)." The CRED/ DAR classification also divides "turf-bare" into several subgroups:

Subgroup: Visible turf on rubble substrate: "Turf algae often cover rubble, which is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral)

> typically of gravel (> 5 mm) and cobble (baseball) size with finer and coarser sediments mixed in, giving the fragments a fuzzy appearance."
>
> ***Subgroup: Visible turf on hard [bottom] substrate***: "Turf algae often appear as fuzzy carpets growing across hard substrates. Hard substrates range from pavement flats to basalt formations to bare carbonate (i.e. coral skeleton) structures. NOTE that turf algae will tend to trap a fine layer of sediment and this still constitutes a turf covered surface and should NOT be classified as Sand."
>
> ***Subgroup: [Invisible turf on] Rubble substrate***: "All hard surfaces are colonized by turf algae within days of being placed in the water. All rubble, which is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral) typically of gravel (> 5 mm) and cobble (baseball) size with finer and coarser sediments mixed in, are covered by turf algae even though these small organisms might not be visible in a photograph. Sometimes they're even difficult to discern by a diver in the field."
>
> ***Subgroup: [Invisible turf on] Hard [bottom] substrate***: "All hard surfaces are colonized by turf algae within days of being placed in the water. All hard substrates are covered by turf algae even though these small organisms might not be visible in a photograph. Hard substrates range from pavement flats to basalt formations to bare carbonate (i.e. coral skeleton) structures."

As such, virtually all hard bottom structure not consisting of living corals or other macrobiota will comprise the "turf-bare" benthic cover in the CRED/DAR scheme. Exhibit 36 shows the percent bottom cover of "turf/bare" at each transect of the CRED/DAR data set. It can be seen that the highest cover of turf/bare bottom occurs uniformly in the nearshore shallow pavement zone along the entire length of the survey area along the length of Kahekili reef. It is important to note that some of the lowest values of turf/bare cover occur on transects in close proximity to the NSG and SSG. In addition, there are no indications of increased turf/bare bottom cover in the deeper reefs in proximity to the seep sites, and no gradients of increasing turf-bare cover in relation to the seeps. Based on this data set, there is no indication that the seep discharge is a driving factor for increased turf algal abundance. Rather, turf/bare cover is the dominant bottom type in the nearshore zone throughout the Kahekili reef.

1-7.4 August 2014 Kahekili Reef Survey

In April 2014, a reconnaissance survey was conducted to gain an initial understanding of the overall setting of the Kahekili reef. The reconnaissance survey was followed in August 2014 with a detailed quantitative field investigation to fully document the biotic setting of the reef system off Kahekili Beach. The overall intent of the reef survey was to evaluate the effects to the ecosystem from the discharge of materials from the submarine seeps near the shoreline.

All fieldwork was carried on August 14-17, 2014 with divers (S. Dollar, E. Hochberg, S. Peltier) working from a 26-foot boat. The in-water survey had the objective of quantifying the spatial distribution of benthic community structure across the Kahekili reef and nearby areas. Survey sites were haphazardly selected across the entire reef from the shallowest accessible areas at the shoreline out to the limit of coral occurrence at the seaward edge of the solid reef structure (i.e., the margin between sand and solid reef).

At each site, field methods consisted of acquiring 50–100 digital photographs of the reef using a camera equipped with a continuous shutter mode. Photographs were oriented perpendicular to the reef surface covering a total area of approximately 5×5 m at each site. Photographs within each site included several metal "T" pipes marked at 10 cm intervals that served as scale indicators. A total of 82 survey sites were visited, 71 of which were within the Kahekili reef extent (defined by visual interpretation of WorldView-2 imagery). The locations of the 71 photomosaics on the Kahekili reef are shown in Exhibit 22.

In the lab, the 50-100 photos from each site were stitched together to form a seamless mosaic (photomosaic) using the software Kolor Autopano Giga v3.6. The 71 Kahekili photomosaics together comprised an approximate area of 1,400 m^2. The remainder of the sites were located at areas to the north and south of Kahekili with fringing reef structure, but without seeps, that could be considered control sites. While the control sites were located in the nearest areas to Kahekili where fringing reef was found, neither of the control sites consisted of the narrow Example mosaics from each of the main reef zones (shallow pavement, inner shallow aggregate reef, outer shallow aggregate reef) are shown as Exhibits 23-28. All photomosaics are contained in Appendix A.

All photomosaic analyses and remote sensing analyses were performed by E. Hochberg who provided the description of the methods below. To analyze a photomosaic, 100 circles were overlain on the image in a 10×10 grid. Each circle had a radius of 75 pixels, which corresponded to areal coverage of 8–178 cm^2 per circle, depending on the pixel dimensions of the mosaic. The dominant benthic type (corals identified to species, turf, upright macroalgae, sand, etc.) within each circle was identified. The identifications of each bottom cover were counted, then divided by the total number of counts equals 100, except for three instances of holes in mosaics) to provide proportional cover for each benthic type. Exhibit 29 shows the results of photomosaic analysis in tabular form.

It is important to understand that the mosaics are not intended to be absolute representations of the reef at the cm-scale. The point of building and using mosaics in this analysis is to gain a better perspective of a reef community than is afforded by a few small (<1 m) quadrats in the same reef area. Even if the software is unable to perfectly align small features, the mosaic as a whole remains the better representation of the local community (Gleason et al. 2007, Lirman et al. 2007). This improved perspective is important for spatial analysis of benthic cover derived from the mosaics, as well as for calibrating and validating remote sensing classification products.

Spatial analysis of field data was performed using Partial Redundancy Analysis (RDA) to test whether distance from the Kahekili seeps can explain the distribution of benthic community structure, while accounting for distance from the shoreline. The basis and method for conducting partial RDA in this setting are explained in the book *Numerical Ecology, Third English Edition* by Legendre and Legendre (2012): "In partial RDA, the linear effects of the explanatory variables **X** on the response variables **Y** are adjusted for the effects of the covariables **W**" (p. 649). Partial RDA is a form of multivariate multiple regression. In this case, the explanatory variables **X** were distances from each of the 71 survey sites to each of the two Kahekili seep groups, i.e., two distances for each survey site. The response variables were the percent benthic cover for the three categories algae, coral, and sand. The covariable **W** was the shortest distance from each survey site to shore.

Partial RDA computes a statistic called "pseudo-F," which is a version of the very well known (among scientists) F-statistic. Next, a permutation test repeatedly randomizes the response variables and recomputes pseudo-F to determine the frequency that random data might produce a values of the statistic higher than that observed. With a suitable number of iterations (1,000–10,000), this frequency is the probability, or *p*-value, for the test.

The statistical software R, with additional community ecology package VEGAN (co-written by Pierre Legendre), was used for this analysis. The function *rda* computed pseudo-F, and the function *permutest* performed the permutation test with 10,000 iterations to find the *p*-value. The analysis was performed once as described, with benthic cover of coral, algae, and sand as the response variables **Y**; distances from survey sites to the two seeps as the explanatory variables **X**; and shortest distance from each survey sites to shore as the covariable **W**. The analysis was then repeated, switching the explanatory and covariables, to evaluate whether distance from shore can explain the distribution of benthic community structure, while accounting for distance from the seeps.

The results of these analyses provide a robust indication of the effects of the seeps on coral community structure. Note that a more complete discussion of the results of the photomosaic analyses in relation to community structure is presented in the expert report of Dr. Eric Hochberg. Given distance from shore as a covariable, distance to the seeps does not explain the distribution of benthic community structure at Kahekili (pseudo-F = 1.17, $p = 0.32$). However, given distance to the seeps as a covariable, distance to shore very strongly explains the distribution of benthic community structure at Kahekili (pseudo-F = 121.6, $p = 0.000099$). These results unequivocally indicate that the seeps do not influence benthic community structure. Rather, it is the proximity to shore that is factor responsible for patterns in the benthic community. As discussed above, proximity to shore is related to both water depth and wave stress, which have been described as the major determinates of zonation of coral reefs in Hawaii. Hence, the results of statistical analyses of field data validate that the Kahekili reef conforms to the general Hawaiian reef typology.

Remote Sensing Analysis was also conducted using the data from the August 2014 field survey. Maps of biotic composition of the offshore marine environment of the Kahekili reef were generated using the benthic cover data generated using photomosaic analysis as “calibration-validation” input. Construction of the maps followed standard procedures for processing coral reef remote sensing imagery (e.g., Andréfouët et al. 2003, Bainbridge and Reicheldt 1988, Green et al. 2000, Mumby et al. 1998). All remote sensing analyses were conducted by E. Hochberg.

A cloud-free, sea surface clutter-free WorldView-2 remote sensing scene of the wider Kahekili area (Honokowai Beach Park at the north to the Westin Maui Resort and Spa at the south) was identified using the DigitalGlobe web-based

ImageFinder tool. The scene (Product Catalog ID 2030010111D11C00) was acquired October 19, 2013 at 11:29 HST. A standard imagery bundle of panchromatic and eight-band multispectral data was purchased through an certified reseller (Spatial Solutions, Inc.). The panchromatic image had 0.5 m resolution, while the multispectral image had 2 m resolution. Imagery was delivered as georeferenced and gridded on the Universal Transverse Mercator zone 4Q projection, based on the WGS84 ellipsoid. A subset of the imagery surrounding the Kahekili reef was "pan-sharpened" using the Gram-Schmidt algorithm in the commercial software ENVI, producing a 0.5-m-resolution, eight-band multispectral image of the study area. A mask of the reef was created by manually digitizing a polygon around the reef edge, and sea surface clutter (whitecaps, boats, swimmers) was also masked.

In ENVI, each of the 71 field mosaic sites was located on the image and used to define a region of interest (ROI) of 20–30 image pixels (71 sites = 71 regions of interest). Additional ROIs were defined through visual interpretation to identify areas of purely sandy seafloor, which were not visited in the field survey. The ROIs were used to construct a maximum likelihood classifier, which was then applied to the full image, associating each pixel to a single ROI. That image was used to look up percent cover values for each bottom-type, producing final maps for coral cover, turf-bare cover, etc.

For accuracy assessment, for each ROI pixel (total of 1,634 pixels), actual benthic cover was compared against predicted benthic cover at levels of 0%, 0–10%, 10–20%, 20–30%, etc. These values together comprise an error matrix with actual cover as columns and predicted cover as rows (Exhibit 30). Correct classifications fall along the main diagonal of the matrix, while misclassifications are off-diagonal. Dividing each matrix element by its column total, then multiplying by 100, converts the matrix of pixel counts to classification rates. Classification accuracy was very good for all levels of each bottom-type; the lowest correct classification rate was 88.9% for turf-bare at 50–60% cover. The high accuracy indicates that the maps are a good representation of benthic community structure at Kahekili.

Exhibits 31, 32 and 32 show the resulting benthic habitat maps for coral, turf algae and crustose coralline algae. Coral cover is low at the shoreline throughout the survey area (Exhibit 31). The nearshore area where the seeps are located characterized by less than 10% coral cover corresponds to the shallow pavement. Within approximately 25 m from shore, coral cover increases sharply to the range of 30-80% with the highest values occurring predominantly near the outer (deepest) edge of the aggregate reef. Irregular areas with zero coral cover on the offshore reef represent sand patches.

The map of turf (Exhibit 32) shows essentially a mirror image of the coral map with highest cover on the nearshore and lower levels (less than 20%) on the offshore reefs. CCA shows a somewhat different pattern with a band of peak values across the center of the reef bench (Exhibit 33).

Exhibit 34 is a amalgamate map that merges cover of the three dominant bottom covers (coral, algae and sand). As with the individual cover maps, it is evident that the reef has a strong onshore-offshore gradient of cover going from algae to coral cover with increasing distance from shore.

Exhibits 35 and 36 are maps showing data from all CRED/DAR surveys with survey sites color coded to correspond to coral and turf abundance, respectively. The patterns shown in these map is similar to that of the remote sensing maps with little coral near the shoreline, and high coral on the outer reef (Exhibits 31 and 32).

It is also apparent from all the maps, as well as the statistical treatment of the photomosaic cover data discussed above that there are no significant abnormalities in coral community composition at the sites of the seep discharges. Nor are there gradients of decreasing or increasing benthic covers with respect to distance from the seeps. The seeps occur in shallow water near the shoreline in a shallow pavement zone where physical conditions prevent significant coral occurrence along the entire shoreline. Hence, while there are few corals growing at the seeps, there are similarly few corals growing at similar depths and distances from the shoreline everywhere else along this coastline. In fact, while the data produced by the reef survey program at Kahekili conducted by the CRED/DAR showed similar zonation, these surveys showed some instances of higher coral cover in the immediate area of the seeps than anywhere else on the reef in the same depth and distance from shore zone (Exhibit 35).

At the time of the August 2014 field study, no substantial growth of upright macroalgae was present in the vicinity of the seeps, or anywhere else on the reef. Upright algae composed a total of 0.18% of cover of the photomosaics and appeared in only 5 of the 71 photomosaics (Exhibit 29). Where it did occur, macroalgae was predominantly colonizing the non-living interstitial spaces between the living branch tips in *Porites compressa* thickets. Species of fleshy macroalgae that have occurred in bloom conditions sporadically in past years on the reef at Kahekili (*Cladophora, Acanthophora, Hypnea, Ulva*) were absent during the August 2014 surveys.

1-8. Historical Consideration of Impacts to Kahekili Reef Structure

CRAMP Data

Much has been said about the magnitude and causes of change to coral cover over time at various reefs on Maui. While the data produced in our 2014 survey depicts the setting at the reef off Kahekili at one point of time, it can only be used anecdotally to reveal changes over time.

Review of data from the Coral Reef Assessment and Monitoring Program (CRAMP) run by the University of Hawaii and DAR reveals important time trends with respect to changes in reef structure at Kahekili. The CRAMP program includes two permanent transect stations at Kahekili, one located at a depth of 3 meters and one located at depth of 7 meters. Both of these transects are located with the shallow aggregate reef zone. Both of these survey stations are located approximately 100 m from the SSG and 250 m from the NSG (Exhibit 2).

Histograms of mean coral cover from the Kahekili CRAMP surveys are shown in Exhibit 37 (found on the CRAMP website http://cramp.wcc.hawaii.edu/LT_Montoring_files/lt_study_sites_Maui_Kahekili.htm). Several important points emerge in examining these histograms. First, the greatest decrease in cover between any two surveys at both sites occurred between 1999 and 2001. Apparently no survey was conducted in 2000 when algae blooms were reported to peak.

Also shown in Exhibit 37 are plots showing regression lines plotted through the coral cover data. Linear regression analyses show trends in coral cover in terms of increases or decreases over time. The regression analyses of coral cover show increases in coral cover at both Kahekili sites over the entire survey period, with the increase at the 3 m site statistically significant at the 0.05 level .

Exhibit 38 shows the results of all of the CRAMP data for Maui survey sites, with the Kahekili sites highlighted in yellow. Examination of Exhibit 38 indicates that along with the two sites at Kanahena Bay, the 3 m survey reef at Kahekili is the only location on Maui that shows statistically significant increases in coral cover. While not statistically significant, the positive regression slope at the 7 m site is the next highest of all the Maui sites. As a result, these data indicate that not only are the reefs at Kahekili not being actively degraded, but rather are improving with respect to increasing living coral abundance. As only one other monitoring location on Maui shows similar increases in coral cover, Kahekili should be considered one of the healthiest reefs within the survey regime on Maui.

Further examination of the CRAMP data provides some insight into the processes driving the documented trend of increasing coral cover. Exhibit 39 shows a time-series of photo-quadrats covering the same exact area of reef on one of the Kahekili transects (not identified whether it is the 3 or 7 m site). In the first photo from 1999 no macroalgae is visible in the frame. In both 2001 photos, numerous clumps of the green algae *Cladophora sericea* can be seen tangled on the coral. *Cladophora* is not visible in any photos beyond 2001.

Rather, in photos from 2003 to 2005 the invasive species *Acanthophora specifera* is visible covering portions of the reef surface. Hence, it can be speculated that the episodes of *Cladophora* abundance resulted in mortality to corals owing to tangling and smothering, as reflected in the decreases in cover documented by CRAMP between 1999 and 2001. Subsequently, once *Cladophora* became absent, the reef began to recover, with regrowth of many of the remaining colonies over the areas left bare where corals were killed. The drop in coral cover evident on both transects in 2005 that is apparent in the histograms in Exhibit 37 correspond to the year where *Acanthophora* was most abundant on the reef. The CRAMP photoquadrat series shows no macroalgae in the most recent survey (2009), with coral cover not substantially different in 2009 than in 1999 (Exhibit 39). In fact, the size of a round white colony of *Pocillopora meandrina* on the right side of the photo-quadrat is substantially larger in 2009 than in any previous year.

While it is presently not clear what factors are responsible for the intermittent occurrence and subsequent disappearance of the algae blooms it is likely that it is part of a natural cycle driven by variations in physical oceanographic factors which may intermittently carry algae from offshore areas toward shore. This hypothesis was first stated in Dollar and Andrews (1997), when the original blooms of *Cladophora* in 1990-1991 disappeared and were replaced by infestations of an alien species, *Hypnea musciformis.* While *Hypnea* has a distinctly different life history and habitat requirement than *Cladophora*, it has also subsequently disappeared from West Maui as a nuisance species).

Owing to the irregularity of algal bloom occurrences at Kahekili, and the rapid decline following these infestations back to low algal cover, it is my opinion that these events are not driven by nutrient contributions to nearshore water by the consistent seep discharge.

Whether or not the occurrence of algae on the reefs causes mortality to corals is natural or man-induced, it can be viewed as one form of intermediate disturbance which results in creation of new bared space available for subsequent re-colonization, thus maintaining peak diversity on the reef. Observations during our field surveys of areas of intact but bared limestone surfaces suggested that indeed there was some degree of coral mortality in the recent past, most likely from the smothering of corals by episodic algal infestations. It was also apparent that active coral regrowth of these bared areas is ongoing, as evidenced by growing edges of intact corals, as well as the sequential CRAMP data. None of the bared areas of reef substratum were being colonized by large accumulations of fleshy macroalgae. In addition, there were no signs of major instances of coral disease nor other signs of reef degradation.

While the cause is not clear, these infestations of several species of macroalgae resulted in deleterious effects to some reef corals in West Maui. The present condition of the reef appears to be in a stage of recovery from past deleterious effects associated with algal aggregations that last occurred in 2008 (according to R. Brock) Repetitive time-course surveys conducted at two sites on the Kahekili reef by CRAMP verify recovery is taking place as coral cover has statistically increased from 2008 to 2012 (the last year that CRAMP data are available). Our comprehensive survey conducted in August 2014 verified that there is no indication that coral cover is being negatively impacted by overgrowth of macroalgae. Rather, all data suggest that the reef is in a recovery period from past events which may have reduced coral cover. As effluent discharge has not decreased significantly since 2008, and coral cover is increasing, there is no support for the claim that seep discharge is negatively impacting the reef.

1-9. Rebuttal of testimony by Jennifer Smith

The remainder of this report is a rebuttal statement to the “Expert Disclosure Report” prepared by Dr. Jennifer Smith dated February 9, 2015. Dr. Smith opines that discharge from submarine seeps in the nearshore area off Kahekili Beach in West Maui is negatively affecting the “health” of corals in the vicinity. In terms of field data, this opinion is based on results of a one-day survey of a small portion of the Kahekili reef that did not include the major reef-building zones (shallow aggregate reef). Data from several other sources, including results of a water chemistry monitoring program conducted by the HDOH, and several time-course benthic monitoring programs including those carried out by the CRED/DAR and CRAMP were also used to formulate this opinion.

My rebuttal will show these data do not support any scientific basis to indicate that there are negative impacts to the reef at Kahekili as a result of materials emanating from the submarine seeps. Rather, these data consistently support the contention that there is no identifiable effect to reef structure and function.

1A. Dr. Smith contends that a “healthy coral reef” is one that is dominated by reef-building species that are actively growing and laying down calcium carbonate (limestone). While this may be true, the scientific literature is replete with discussions of how many open coastal reefs, and particularly shallow pavement zones, in Hawaii are not accreting calcium carbonate owing to the constant effects of wave impacts which prevent such accretion (ex. Grigg and Maragos 1974, Grigg 1998, Fletcher et al. 2008).

Further, Dr. Smith goes to say that if a reef becomes dominated by fleshy seaweeds (turf algae and macroalgae) it is no longer considered a healthy reef and will begin eroding away. All evidence presented in my testimony above based on work from all parties indicates that the only zone of the reef dominated by turf algae is the shallow pavement zone that has not been an accreting reef for at least 2,000-3,000 years (Grigg 1988). While this zone of the reef may indeed be eroding, it has been doing so for millenia because at the present stand of sea-level, it is too physically harsh for corals to grow. In the deeper aggregate reef zones where physical conditions allow corals to settle and grow, data from all surveys (including the survey by Dr. Smith) indicates that corals are indeed alive and contributing to reef accretion. Hence there is no support for the statements indicating the entire reef at Kahekili is eroding, and thus “unhealthy” owing to algal overgrowth.

1A2. Dr. Smith contends that coral cover at Kahekili Beach has declined over time. This conclusion is based on data produced by what is termed “an extensive and rigorous coral reef monitoring program that has been in place for over a decade at several sites around the Island of Maui including Kahekili Beach Park.” It is stated that the monitoring was initially established by the PWF in 1994, and in 1999 the monitoring was “assumed” by DAR/CRAMP. Exhibit 1 of Dr. Smith’s Report reproduces a map of monitoring locations around West Maui showing trends in coral cover over time. As no other data from these above-mentioned monitoring programs is included in the Smith Report, it is assumed that her conclusions regarding changes in coral cover over time are based on the information in Exhibit 1 (hereafter called SE-1). It should also be noted that the figure in SE-1 is cited as Williams et al. 2012, although no such reference Is listed at the end of Dr. Smith’s report, so the actual origin of this figure is not known. It should also be noted that Dr. Smith references Jokiel *et al.* (2004) as the source of CRAMP data in the graph in SE-1 that extends to 2012. This citation is obviously erroneous. The Jokiel *et al*. (2004) evaluates the CRAMP data for the years 1999 through 2002.

As a first consideration, it is not accurate to compare data collected from the PWF and CRAMP surveys as these two programs differed substantially in methodology. The PWF survey consisted of three adjoining “sites” which spanned a linear distance of approximately 800 meters across the reef, while the CRAMP survey sites are contained within an area 100 meters long (see Exhibit 40 from Brown, undated report). In addition the sampling methodology was substantially different between these two programs. Transect methods for the PWF survey consisted of “setting out 3 nylon lines of 50 meters in length along depth contours separated by a distance of 5 meters. A 1 m^2 PVC quadrat was laid over the coral substrate at predetermined intervals (10 meters) resulting in 5 quadrats per transect. At 81 intersection points under a nylon grid spaced 10 cm apart bottom cover was recorded. No geographical coordinates are given for the locations of the PWF sites, and no methods are described reporting how site locations were replicated on subsequent surveys.

The CRAMP method has been modified several times over the course of the program. As a result is not likely that the final iteration would end up with a similar protocol as the PWF methods conducted years before, and indeed it does not. The CRAMP method consists of running a 100-meter “spine” across the reef with ten 10-meter long transects randomly chosen, located either on the spine or one meter on either side of it. The location of the spine is marked by stakes driven into the reef to ensure replication during all surveys. Surveys are done using photo-quadrats taken every meter along each 10-meter transect, with the camera maintained at a distance of one-meter from the reef surface. Twenty-five points per photo are analyzed to arrive at an estimate of benthic cover.

These methods are clearly different in both areal extent and analytical results. While they may serve to show time-course changes internally (within each program), they cannot be inter-compared with any degree of precision.

Investigation of the actual data that was apparently used to compile SE-1 reveal a multitude of errors with both the data presentation and interpretations. Exhibit 41 shows Table 2 from an undated report entitled “Saving Maui’s Reefs” by E. K.

Brown, who conducted the PWF surveys. Exhibit 41 also includes a summary table that I added showing the average values of coral cover from each of the PWF Kahekili sites and for each survey year.

Inspection of the data shown in Exhibit 41, and that are shown in SE-1 show clear discrepancies. While there is no label on the vertical axis of the graph in SE-1, it is assumed that the cross-hatching represent 10% intervals. It is also of note that the x-axis labels showing years are ambiguous with no clear indication of which bar corresponds to which year. While "55%" appears over the right hand side of the Kahekili bar graph, there is no value of 55% in the summary table in Exhibit 40. The only bar indicating close to 55% cover is the first one which is the value from the first survey result from 1993 at Site 1 (58.6%) (No data was collected at Sites 2 and 3 in 1993). In 1994, the first year that Dr. Smith indicates that the PWF survey was conducted, the average cover was 47.9% and not 55%. Hence, the often-cited value of the original coral cover at Kahekili Park (55%) cannot be verified in the data base from where it supposedly came.

Inspection of the set of bar graphs earlier than 1999 in SE-1 shows no correspondence to the pattern shown for the data in the PWF report (Exhibit 41). A decreases between what might be 1996 and 1997 on the graph is an increase in the data table, and an increase between 1997 and 1998 on the graph is a decrease in the table. As no information is provided as to how the values shown in SE-1 were derived, and these data do not correspond with the actual reported PWF data, they cannot be considered a valid representation of coral cover at Kahekili.

However, the PWF data does indicate that there is substantial variation in coral cover over the geographical extent of the reef. Average values of coral at Sites 1, 2 and 3 are 50%, 54% and 30%, respectively. Hence, collected over the same years, there is almost half the cover in one sector compared to the other two within the reef. The change in cover between sites on the Kahekili reef from the

PWF data (54-30=24%) is larger than the supposed change over the Kahekili reef between 1994 and 2012 shown in SE-1 (55-37=18%). With such variability within the reef, it is not valid to consider the averaged data accurately represent changes over time for an entire reef system.

In fact, examination of the CRAMP data strongly supports a conclusion opposite to that of Dr. Smith that "these annual surveys show a clear decline in living cover at Kahekili." Data from the DAR/CRAMP website (http://cramp.wcc.hawaii.edu/LT_Montoring_files/lt_study_sites_Maui_Kahekili.htm) summarizes all of the survey results from inception of the program in 1999 to 2012 (if more recent data exists, it is not yet entered). Exhibit 37 shows all mean cover data from the 3 m and 7 m stations at Kahekili along with plots of trends of change over the period of 1999 to 2012.

Rather than showing a decrease in coral cover, the statistical trend for both transects is increasing as defined by positive regression slopes. Examination of Exhibits 37 and 38 reveal that there has been a statistically significant positive change (increase) in coral cover at the shallow (3 m) Kahekili site, and a non-significant positive change (increase) in coral cover at the deep (7 m) Kahekili site. Although both of the CRAMP sites are located about 100 meters away from the SSG, the submarine seeps are located in water shallower than 3 m. Thus, the shallow 3 m CRAMP site would be expected to be more influenced by the seeps. (A USGS report [Swarzenski et al. 2012] states that net currents in the area are alongshore). The fact that the shallow site showed a statistically significant increase in coral cover does not support the contention that the seeps are affecting coral cover.

Examination of all of the CRAMP stations on Maui indicates that Kahekili is one of two sites among the total of ten that has increases of coral cover at both shallow and deep transect locations (Kanahena Bay is the other) (Exhibits 37 and 42). Hence, based on these CRAMP data, over the last 12 years the reef at Kahekili has shown greater increases in coral abundance than practically anywhere else on Maui where CRAMP monitoring takes place. As a result, there is no validity in the opinion of Dr. Smith that "coral cover at Kahekili Beach has declined over time." Rather the data support the opposite conclusion that coral cover is actually increasing.

To illustrate her apparent lack of any critical examination of the CRAMP data, Dr. Smith states that "The extent to which this reef (Kahekili) is struggling is even more apparent when one compares its trajectory (change over time) to sites devoid of human impact, such as Molokini, where coral cover has not changed or has even increased over the past two decades." This statement is clearly false as examination of Exhibits 38 and 42 show that CRAMP data indicate that there is actually a decrease in coral cover at the deep Molokini site, although the decrease is not statistically significant. The positive regression slopes for both the shallow and deep Kahekili sites (0.90 and 0.47, respectively) are greater in magnitude than the positive regression slope for the shallow Molokini site (0.15), indicating that coral cover increased faster at Kahekili compared to Molokini during the time frame of 1999 to 2012. Thus, in terms of the CRAMP data, when comparing Kahekili to Molokini, Kahekili must be considered to be a "healthier" reef in terms of more rapid increases of coral cover.

Dr. Smith also opines that "The fact that living coral makes up much less than half of the reef floor at Kahekili indicates a reef in distress (P. 3)." None of the ten CRAMP sites on Maui in water 3-4 meters deep had coral cover covering more than half the reef floor. At only two of the ten sites (Molokini and Olowalu) did coral cover constitute greater than 50% cover, and both of these sites were in deep water (8 meters or greater). Based on the CRAMP data from 1999 to 2002, the average coral coverage of all 152 CRAMP stations throughout the main Hawaiian Islands was 20.8%, with only 20 of the 152 stations having higher than 50% cover (Jokiel et al. 2004). The statement that cover of less than 50% indicates a "reef in distress" demonstrates a complete lack of understanding of coral reef structure in Hawaii. In fact, it is likely that there is not a single reef anywhere in Hawaii (including the pristine Northwest Hawaiian Islands) with total coral cover exceeding 50% when the entire reef from shallow nearshore pavement to outer reef is averaged.

Dr. Smith uses the CRED/DAR data set to justify her opinion that the Kahekili reef is being overtaken by turf algae by constructing stacked bar graphs that show that "bare/turf" (the category used in the CRED/DAR reports) is the single highest benthic cover on the Kahekili reef (Smith Exhibit 3; SE-3). While total cover of any one component is not especially relevant in determining the condition of a total reef community without considering the physical setting of the reef, several aspects of this graph contradict her opinions about turf algae taking over the reef. First, it can be seen in SE-3 that since 2009 the CRED data show that total coral cover has gradually increased, as has CCA. As Dr. Smith states, both of these groups are considered reef builders in terms of producing calcium carbonate reef structure, and an increase in both of these categories indicates what would be deemed a healthy reef. Turf algal cover, however, is not consistently increasing, with values in the most recent survey (2013) lower than in 2009.

It is also important to understand that the classification that Dr. Smith refers to as "fleshy turf" is actually termed "Turf-bare" in the CRED/DAR classification scheme. In fact, according to the CRED/DAR classification scheme, the term "fleshy turf" is contradictory in that if an alga is "fleshy" it is macroalgae, and not turf. The turf-bare group includes sub-categories defined as "invisible turf" which is essentially bare bottom that has not necessarily been colonized by anything or by such small alga cells that they are not visible in photographs. As such, this "catch-all" category includes what would be considered bare surfaces and not "fleshy turf." As a result, the category of "turf-bare" in the CRED/DAR data overestimates actual established turf algal mats that Dr. Smith alludes to. Such bare surfaces do not pose a threat of growing over coral.

Analysis of the CRED/DAR data in terms of spatial distribution indicates clearly that turf algae constitutes the major benthic cover in nearshore areas, as is the case on virtually all Hawaiian reefs. Exhibit 36 is a satellite image of the Kahekili reef overlain with colored circles that represent "turf-bare' cover from the pooled CRED survey data set from 2008 to 2013. Also shown are the locations of the NSG and SSG. It is evident that the abundance of turf-bare cover is highest in the nearshore area with decreasing abundance with distance from shore. As mentioned above, this is the normal distribution on open coastal Hawaiian reefs, as physical conditions of nearshore areas prohibits coral colonization. Turf-bare cover in the CRED/DAR map is consistent in value along the entire reef shoreline, and there is no indication of gradients of increasing turf-bare cover with proximity to the seeps. In fact, some of the lowest values of turf-bare cover in the nearshore zone occur close to the seeps. Regression analyses of turf-bare cover as a function of distance from the shore indicates significant ($p<0.05$) negative correlations during all eight CRED surveys, while there are no significant correlations between turf-bare cover and distance to the nearest seep (Exhibit 43. provided by E. Hochberg). These analyses indicate that there is no effect to abundance of turf-bare cover as a function of distance to the seeps, but rather that turf-bare cover is in response to physical environmental factors that drive reef zonation.

The 3-dimensional graphs in Dr. Smith's Exhibit 8 (SE-8) represent data from the 2013 NOAA surveys (these are actually the CRED/DAR surveys discussed above). The two NOAA surveys at Kahekili in 2013 consisted of 22 transects in April and 26 transects in September for an annual total of 48 transects. However, only 20 data points are shown in each plot in SE-8, indicating that some data was omitted, even if the data represent only one of the two surveys in 2013. As it is difficult to determine which data were omitted, the fact the plots do not represent the entire data set is enough to invalidate this exhibit.

Although these graphs are difficult to interpret, it appears that the pattern they reveal is identical to what is described above in terms of the typical Hawaiian reef zonation scheme. The longitude scale represents distance East to West, which is equivalent to onshore to offshore. The four red and pink circles which represent samples collected near the seeps also appear to be the samples collected nearest the shoreline (lowest longitude). When these graphs are re-plotted with stems on the data points to allow determination of the longitude, it is apparent that the samples collected nearest the shoreline had the highest turf algae and lowest coral (Exhibit 44, prepared by E. Hochberg). The oversimplified interpretation of Dr. Smith that because turf algae occurs as a dominant benthic cover near the shoreline means the reef is degraded is not supported by the NOAA CRED data that she plots. Rather, these plots supports the zonation pattern of the Kahekili reef characterized by a nearshore zone of shallow pavement which is not suitable for coral colonization.

1A3. Dr. Smith states that the reef at Kahekili has a recent history of seaweed blooms. Dr. Smith is correct in stating that there have been documented blooms of fleshy seaweeds in the Kahekili area as well as at other regions of West Maui. However, there is no evidence that the material from the seeps caused any of these blooms. Based on the irregularity of blooms and subsequent disappearance, it is not plausible that they are driven by discharge from the LWRF which has been ongoing uninterrupted for approximately 30 years. It is far more likely that blooms are caused by episodic oceanographic events which result in onshore transport of algae from offshore locations. It is important to note however that no blooms have occurred for at least the last 7 years (2008 as reported by R. Brock). As the LWRF facility has been in operation over these 7 years, there is a distinct disconnect between the submarine seeps and macroalgae blooms.

With the near absence of macroalgae on the Kahekili reef at present Dr. Smith now states that “fleshy turf algae” are dominating the reef and overgrowing corals, and that “it is only a matter of time before the entire reef is overtaken by this turf algal community." This statement is faulty in a number of ways. First, as detailed above, the CRAMP data shows that coral cover at both Kahekili stations is actually increasing, rather than decreasing. If turf algae was encroaching on corals as suggested, there would be no such steady increase in coral cover, but rather the opposite. In fact, if this statement were true that turf algae consistently overgrows corals, there would presently be no coral at all on the reef. Clearly, this is not the case.

Secondly, as discussed earlier in this report, turf algae is a natural component of ALL reefs, particularly in the nearshore zones where wave stress prevents coral settlement and growth. Turf algae are the first to colonize vacant reef surfaces and cover essentially every nonliving hard surface on a reef. As such, they are frequently the dominant algal constituents in shallow coral reef ecosystems. The area where the NSG and SSG are located (~3-25 m from shore) constitutes such a nearshore zone, and are colonized almost exclusively by turf algae.

Reports by other scientists also do not support Dr. Smith's contention that algal turf is proliferating in response to increased nutrient loading from seep discharge. In fact, it is suggested that the opposite is true and that turf algae is does not require elevated nutrients. Littler et. Al (2006) report that domination by turf algae suggests not only desirably <u>low</u> nutrient levels (bottom-up) but also an inadequate herbivory (top-down) component required for healthy coral-dominated reefs. Algal turfs have been shown to form extensive horizontal mats under <u>reduced</u> nutrient-loading rates (Fong et al., 1987) or infrequent nutrient inputs (Fujita et al., 1988). These reports of turf algae thriving in areas of low nutrients by well-known researchers directly contradicts Dr. Smith's assertions that turf algae occurs, and is proliferating at Kahekili in response to increased nutrient loading from the submarine seeps.

1A4. Dr. Smith states that "corals are suffering mortality due to overgrowth by turf algae, the most dominant member of the reef community at Kahekili." This statement is based on an unpublished report by Ross et al. (2011) entitled "Characterization of "dead zones" and population demography of *Porites compressa* along a gradient of anthropogenic nutrient input at Kahekili Beach Park, Maui." It should be noted that this title does not accurately represent the content of the report as it contains not a single measurement of any anthropogenic nutrients nor reference to other nutrient data. In fact, in the conclusions there is not a single mention of any type of measurements of nutrients much less establishing a response to a "gradient of anthropogenic nutrient input."

In addition, this report concentrated on effects to the coral species with the growth form most susceptible to physical damage from wave action (*Porites compressa*). As described above, *P. compressa* occurs predominantly on the slope of the outer aggregate reef. This zone is the most geographically removed from the seeps which occur in the nearshore pavement zone. Hence, without any data, there is no basis to expect than any physical damage to *P. compressa* is a response to seep discharge.

Results of the study showed that "Algal competition was the most common cause responsible for 77.0% of all observed mortality events followed by *Alphaeid* shrimp competition (18.3%) and other (4.7%) including snail and fish predation, sedimentation stress, and bleaching." However, it is also stated that there were significant relationships between January incidence of mortality and algal competition (p=0.001, r = 0.699) and sediment composition with an increased incidence of mortality in transects with higher proportions of terrigenous/silicate components in their sediments (p=0.029, r = 0.562)." In addition "*P. compressa* prevalence of algal competition varied significantly with January wave action measurements (p=0.04, r= 0.689) with higher levels of wave action leading to higher levels of algal competition."

As algae are not likely to grow faster in January when water temperatures are cooler than in summer, it is likely that these results reflect a response to *P.*

compressa communities to impacts from increased wave stress during the winter months. What the Ross et al. (2012) report shows is simply another example of how wave impacts affect coral community structure (documented in Dollar and Tribble 1992, Grigg 1998, Fletcher et al. 2008). Winter waves preferentially affect the coral species with the growth form most susceptible to breakage (*P. compressa*) and sediment scour. Such breakage and abrasion from sediments to intact colonies result in creation of newly bared surfaces consisting of dead coral. Turf algae is the first colonizer of this newly created substrata. Hence, the occurrence of more turf algae in the areas of more broken and dead coral primarily during periods of high surf is not a response of turf outcompeting living corals, but rather turf colonizing already dead coral surfaces.

In addition, the results of Ross et al. (2012) indicate that "Prevalence of turf algal competition in all species of corals ranged from 0 to 3.4% with a mean of 1.4% of colonies affected." Thus, this statement can be interpreted to mean that less than 2% of the coral colonies on the survey transects contained any fraction of contiguous turf algae. Such a result does not suggest that turf algae are taking over the reef as an average of 98.6% of the corals had no associated turf. In addition, none of the transects in the Ross (2012) study were located in the seep areas, so no connection can be assumed between seep discharge and turf algae competition.

1A5. Dr. Smith states that the decline in reef health at Kahekili is broadly acknowledged among the scientific community and government agencies. This statement is supposedly supported by a quote from the USGS report (Swarzenski et al. 2012) that "Over the past decade, there has been a notable change in bottom type at this location; areas once covered by abundant corals are now covered mostly by turf algae or macroalgae, suggesting a likely local nutrient imbalance." However, examination of this USGS report indicates that the sentence quoted by Dr. Smith is incomplete, resulting in a distinct change in meaning and context. The entire sentence reads…""Over the past decade, there has been a notable change in bottom type at this location; areas once covered by abundant corals are now covered mostly by turf algae or macroalgae, suggesting a likely local nutrient imbalance <u>*that warrants further investigation*</u> (underline italics indicates portion of sentence omitted by Smith). This sentence appears in the Introduction of the report and is simply stated as one of the justifications of the study, and not a result of the study.

When the "Results and Discussion" of the USGS report are examined, the first sentence of the "Neashore Mapping" section reads: "Preliminary evaluation of the underwater video and acoustic backscatter imagery suggest the Kahekili/Honokowai reef tract supports medium to high coral cover from just south of Kahekili Beach Park to the northern extent of our survey in north Honokowai, with the densest coral cover observed offshore of Honokowai Point and Kahekili Beach Park. The dominant coral species observed included *Porites compressa*, *Porites lobata*, *Montipora capitata*, and *Pocillopora meandrina*. Live coral is restricted to water depths between approximately 3 and 20 m, with highest coral coverage between 10 and 15 m." These statements from the USGS report do not in any way support the contention that the coral has been replaced by turf algae or macroalgae and, in fact, this report makes absolutely no mention of algal cover within the survey area, and in no way can be interpreted to suggest that "the decline in reef health at Kahekili is broadly acknowledged among the scientific community and government agencies."

In addition, while the USGS work included measurement of nutrient and other water chemistry constituents within, and directly over the seeps, this work does not include any measurements at any horizontal distance away from the seeps, particularly over the living reef that they mapped. Ambient seawater salinities directly above the vents were reported by USGS to be consistently between 34 and 36 ppt, within the range of open-ocean salinities (~35 ppt). The USGS current measurements off Kahekili showed that there was net alongshore flow, and therefore net transport of nutrient-laden water to the south from the vent site towards Keka'a (Black Rock) rather than offshore over the reef. Hence, while salinities directly over the vents indicated near complete dilution of vent waters to background oceanic conditions, whatever dissolved materials originating from the seeps would be carried alongshore over the shallow nearshore pavement, rather than seaward over the reef. These results and the statements in the USGS report discussed above do not support Dr. Smith's contention that the reef at Kahekili is declining. Rather, the data presented in this report suggest the opposite: while there is detectable discharge of groundwater and associated chemical constituents from the seeps, this discharge is rapidly diluted to background concentrations, with net distribution over the reef zone where corals do not occur. There is no indication that this discharge is negatively affecting coral reef structure and function.

On the contrary, there is evidence that government agencies recognized that water quality at Kahekili is not impaired by seep discharge. Recently, the United States Environmental Protection Agency (EPA) approved the State of Hawaii Water Quality Monitoring and Assessment Reports which delisted the Kahekili area as an impaired water body in terms of total nitrogen, total phosphorus and nitrate-nitrite (Exhibit 14).

The delisting does not support Dr. Smith's assertion that "At both state and federal levels, expert agencies concur that the reef at Kahekili is in serious trouble, with algal growth from excessive nutrient inputs a significant concern."

1B2. Dr. Smith states that "The 'coral reef community' around the seeps where wastewater from the LWRF is emerging is dead." As described above, this statement can be considered technically true as the immediate area where the seeps occur is either a bed of sand (NSG) or on the nearshore shallow pavement (SSG) where corals do not naturally occur. However, it cannot be shown that the cause of the dead reef is discharge from the seeps, as Dr. Smith implies.

Dr. Smith bases her statement on the results of a benthic photo-quadrat transect survey that she conducted at the site of the NSG and SSG (described on P. 1 of her report). While there are a multitude of flaws in the conclusions from this study, the most significant defect is that Dr. Smith did not include a control station in her experimental design. Scientific controls are a part of the scientific method that are required for any experiment, and the lack of any control stations, or other survey stations that do not originate at the seeps, is in itself reason to invalidate all conclusions of the survey.

In the Smith survey, six transects were investigated, three originating at the SSG, and three originating at the NSG (Smith Exhibit 9). Conclusions are based on results of these surveys in relation to the test factor (discharge from the seeps). However, without conducting a set of similarly oriented transects at a location that did not originate at the seep groups, it is not possible to determine whether it was seep discharge or other environmental factors that were responsible for the observed results. Based on the geomorphic and biotic zonation of the Kahekili reef (discussed earlier in this report and below), it is likely that had a control site been located along the Kahekili shoreline further north or south of the seeps, results would have been identical to the results at the seep sites. If such identical results had been obtained at these non-seep sites, the survey would provide scientific evidence that the seeps were not affecting coral reef structure. The conclusion reached by Dr. Smith could only be verified if results of transect surveys at a control site showed a significantly different result than at the seep sites (e.g., higher coral, lower turf). Without such a control, no such conclusions can be validated regardless of the resulting data.

In addition to the lack of a control site, the other major flaw in the experimental design is the mixed orientation of the transects with respect to the shoreline (see Smith Exhibit 9). The North and South transects are oriented parallel to the shoreline and cross the shallow pavement zone in their entirety. The West transects, oriented perpendicular to shore supposedly originate at the seep locations on the shallow pavement and extend offshore into the shallow aggegate reef habitat. Hence while the North and South transects remain within a zone, the West transects cross between zones. As such the transects cannot be considered equivalent and cannot be validly compared. A correct experimental design to achieve Dr. Smith's intent would have been to align multiple transects to the north and south of the seeps (and control sites) parallel to the shoreline at increasing distances from the shoreline. It should also be noted that the length of the West transects (50 m) only extended over the approximate inner one third of the reef. Hence, the major reef building zones that occur on the outer two thirds of the reef platform were not surveyed, resulting in an underestimation of the condition of the entire reef.

Other flaws in the survey method involve the misstated reef area that the survey covered. It is stated that the survey focused on a "300 m^2 portion of the coral reef at Kahekili". For 300 m^2 of the reef to be surveyed in six transects, each transect would be required to cover 50 m^2. Examination of the photographs used in this analysis reveals that there were 25 photographs per transect. Hence, for a coverage of 300 m^2, each photograph would require coverage 2 m^2. With the proportions of a standard photographic frame (1 m x 0.66 m) each photograph would require photo dimensions of 1.74 m x 1.15 m to contain a reef area of 2 m^2. Examination of all photographs indicate the area coverage is generally less than one-half this dimension. Thus, the statement that the survey covered an area of 300 m^2 is not accurate. In fact, examination of the transect photos indicates that the total area of coverage is less than half this area. It is also important to note that the photomosaic method that we employed covered a total area of about 1400 m^2, approximately 10 times larger than the area of reef surveyed in the Smith survey.

Finally, with respect to survey methodology, there is no inclusion of geolocations (GPS coordinates) of the transects. This omission is critical in that it prevents any checks on the data with respect to such factors as distance from shore, and actual proximity to the seeps. As a case in point, the GTS has documented that the NSG occurs in an area that is essentially a sand hole (Appendix B is a video clip of the NSG showing bubble streams emanating from a bed of sand). Yet, no sand occurs in any of Smith's transect photos of the NSG. The inability to verify the location of the transects in light of the appearance that they did not really originate at the NSG puts all of the results in question.

Dr. Smith's conclusions drawn from the results of the transect survey are not valid. Smith's Exhibit 12 shows results of the transects in graphical representations (no data tables are presented). At both the NSG and the SSG, the resulting patterns are similar: coral cover increases progressively with distance from the seeps on the west transects (onshore-offshore), while coral cover increases substantially less or not at all with distance from the seep in the north and south (alongshore) directions. The plots of turf algae are essentially mirror-images of the coral plots with turf decreasing with distance offshore (west) along a much steeper gradient than alongshore (north and south). While regression lines are fitted through the data in Exhibit 12, there are no confidence limits shown, and there is no mention of whether these regressions are significantly different than zero. Without showing the regression statistics, the statement "in five out of the six transects surveyed, coral cover increases significantly as you move further away from the seeps" cannot be verified. In fact, visual examination of the graphs suggests that neither of the south transects show significant increases in coral with distance from the seeps.

The conclusion drawn by Dr. Smith is that these results indicate that the seeps are responsible for the observed gradients. For this result to be true, the null hypothesis must be that the only factor affecting coral/turf occurrence is seep discharge: if the seeps were absent coral would cover the entire bottom, and turf would be absent in all photos on all transects. If this was the case, then the gradients of coral and turf cover should be identical in all directions. This is clearly not the case. Rather the steep gradient in the westerly direction do not compare to the much less steep gradient to the south, and no gradient to the north.

Instead, these results indicate that the transects bisect different reef zones rather than reflect any effect from the seeps. Throughout her expert report, Dr. Smith ignores the concept of reef zonation, which is one of the most important factor in describing the structure and function of coral communities (See review of geomorphic reef zonation by Blanchon [2011]). As stated by Blanchon, "shallow coral assemblages show a distinct zonation as wave energy, and hydrodynamic disturbance varies with depth and margin exposure (i.e., distance from shore)." This generalized pattern is exactly what is observed throughout the reef at Kahekili where coral cover is controlled by wave action and proximity to shore.

Rather than reveal effects of seeps, the Smith transects depict and verify the zonation scheme of the reef. The "west" transects, which are oriented perpendicular to shore bisect the shallow pavement zone and extend into the shallow aggregate reef, as evidenced by the increasing coral cover and decreasing turf with distance from shore. The "north" and "south" transects, oriented parallel to shore only cross through the shallow pavement zone, as evidenced by the low coral cover and high turf throughout. Such low coral cover and high algal turf cover on the shallow pavement represent the typical structure of all open coastal reefs throughout Hawaii. To ignore this basic concept of different habitats or zones across the reef in drawing any conclusions regarding coral abundance along spatial scales is not valid science.

1B3. Dr. Smith states that "The water emerging from the seeps at Kahekili has physical and chemical properties that harm the reef." While Dr. Smith's professional opinion is that "there is no question that water from the LWRF is flowing out of the nearshore submarine seeps and onto the coral reefs at Kahekili" there is no quantitative data to support this opinion. As noted above, the USGS report made no measurements of water chemistry in the ocean anywhere but directly over the seeps. Similarly, the HDOH seep monitoring stations were located in the water column directly over the seeps and not anywhere at greater distances from shore over the reef. The GTS also did not include any measurements of water chemistry in the water column anywhere at Kahekili except directly over the seeps. The only water chemistry data collected anywhere over the shallow aggregate reef where corals grow at Kahekili is from my survey which consisted of sampling surface, mid-depth and bottom samples along a series of nine transects that extended from the shoreline to the open coastal ocean, spaced along the entire Kahekili reef. While an elevation in inorganic nutrients was detected over the seeps it was restricted to an area within the boundaries of the shallow pavement zone. Hence, there is no data to support Smith's opinion.

Items 1B3a-1B3e are a litany of generalized discussions describing how extremes of dissolved nutrients, pH, salinity, temperature and dissolved oxygen can induce negative impacts to coral reefs. While these generalized statements are undoubtedly true in situations where such extreme conditions occur, they cannot be shown to be the specific case at Kahekili. Dr. Smith fails to point out that all groundwater is naturally lower in pH and salinity than seawater and that, depending on the sources of water contributing to the groundwater and their flow path in the aquifer, temperature, dissolved oxygen, and nutrient concentrations in groundwater can vary considerably from seawater.

Besides the lack of recognition that the Kahekili reef is composed of several distinct geomorphic zone, the most significant fault of the Smith testimony is the assumption that groundwater pumped from inside the shallow pavement (the limestone framework of the reef) through steel piezometers pounded into rock surface represent the water chemistry that comes into contact with the coral community. Rather, to determine the effects to the shallow aggregate reef where coral occurs, it is necessary to evaluate the composition of the water column in the same area. As described above, the only water sampled in the ocean by the HDOH study, USGS study and the GTS was directly over the seeps located in the shallow pavement zone of the reef; no water samples from these three surveys sampled any locations over the shallow aggregate reef.

As the groundwater from the seeps is less saline than the receiving water in the ocean, in the absence of any turbulent mixing the seep discharge will rise to the surface of the water column. To reach the shallow aggregate reef, these waters must then be transported in an offshore direction and then mixed downward to the benthic surface. It has been noted in the 2012 USGS report that net current transport is alongshore, indicating that the net transport of seep discharge is not across the reef into the zones where corals occur. While mixing of seep water to the reef surface in the zones where corals occur is physically possible, the reality of it is that there will not likely be any detectable concentrations of seep water in the shallow aggregate reef areas owing to the extreme dilution that would occur during the mixing processes. Hence, the highest possible concentrations of seep water in the oceanic water column will be directly over the seeps. As described above, results of the USGS study indicate that water above the seeps showed only slight freshening relative to open-ocean salinities, indicating high levels of dilution. This "slight freshening" corresponds to the highest contribution of seep water to the overlying ocean.

The representations of the HDOH data shown in Dr. Smith's Exhibits 13-15 and 19 also support the conclusion that water emanating from the seeps does not have a major effect on the quality of the marine water column. It is important to note that in these Exhibits the representations of HDOH "seep-bottom" are in actuality the groundwater samples collected from within the reef framework using peristaltic pumps on shore that suck water from steel piezometers driven into the reef rock. These values do not represent ocean water collected near the bottom of the ocean floor.

HDOH water quality standards for "open coastal waters" apply only to water sampled from the water column, and not from groundwater within the reef rock. Hence, none of the values labeled "seep bottom" in the HDOH data set are applicable to open coastal water quality standards. As a result, the values presented in Table 1 summarizing compliance of HDOH samples with HDOH standards are invalid. For instance, while it is stated in Table 1 that 59.26% of the TN samples exceeded the DOH 2% standard, examination of SE-13(C) reveals that no samples from the water column surface and mid water samples came anywhere close to the 2% limit of 350 µg/L, and only two samples exceeded the geometric mean standard of 150 µg/L. Similarly, while Dr. Smith indicates in Table 1 that 100% of the samples exceeded the DOH limit for TP, in actuality only 5 of the 144 water column samples, or 3.5% exceeded the 2% open coastal waters limit.

When the concentrations of Total Nitrogen (TN) and nitrate + nitrite from all three sampling points are plotted on the same graph (center graphs of Exhibits 13 and14) it can be seen that the concentrations within the seeps increased starting in about May 2013 and remain elevated in the range of 2,000-5,000 µg/L and 1,000-2,500 µg/L, respectively, throughout the remainder of the sampling program. The cause of this increase is thought to be related to increased levels of chlorination of the LWRF effluent, which reduce the rate of denitrification (nitrate reduced to N_2 gas) during transit in the rock strata between the injection wells and the seeps at the shoreline. However, while the values within the reef rock increase substantially, the mid-water and surface values remain consistently low throughout as reflected by the nearly flat line in the plots. At the NSG, the maximum value of nitrate + nitrite within the seeps (seep bottom) is 5,560 µg/L (Exhibit 13). Just above the seeps there is a maximum value of 65 µg/L in the mid-water and 63 µg/L in surface samples. At the SSG, the maximum value of nitrate + nitrite within the reef structure (3,540 µg/L) is matched by maximum water column values of 44 µg/L in mid-water and 60 µg/L in surface waters. Thus, only about 1-2% of the elevated levels of nitrate + nitrite in the seeps can be measured in overlying waters. Similar calculations for TN show that a about 2-14% of the elevated levels in the seeps reach the water column, while about 6-10% of elevated TP reaches the water column.

Examination of the HDOH TP data reveals that it does not reflect the same pattern of consistent elevated seep values since mid-2013 (SE-15). The absence of corresponding increases in TP similar to TN reflect the lack of an equivalent anaerobic reducing process for phosphorus analogous to denitrification of nitrate nitrogen. While there was a period during 2013 when some values of TP in the water column were above HDOH standards, such occurrences did not occur during 2014 when all water column samples were in compliance with HDOH standards (SE-15).

The discussion of the dire effects to coral from low pH are also not supported by the data. Table 2 and Exhibit 19 of the Smith Report shows mean pH values from the HDOH data set. While pH of groundwater pumped out of the interior of the shallow pavement area has a low pH, the mean pH in the ocean water column is nearly identical with water from the Kahekili control water column, and higher than pH in water from other West Maui sampling sites that are not in the vicinity of the seeps (Black Rock, Ukumehame). As a result, it cannot be concluded that the seeps are resulting in lowering pH on the shallow aggregate reefs at Kahekili.

Similarly, dissolved oxygen concentration is lower within the interior of the shallow pavement area at the seep sites (Smith Report, Table 3, Exhibit 19). Within the water column above the seeps the concentration of dissolved oxygen is within 0.07 mg/L of the Kahekili control sites, and higher than two of the three other West Maui sites. As reported above, the 2012 USGS survey found salinities of 34-36 ppt over the seeps, which are essentially values of open coastal marine waters. In sum, none of the existing data indicate that the seep discharge is influencing water quality directly over the seeps to a degree that could affect shallow aggregate reef community structure and function. Plots of HDOH data for temperature, salinity, dissolved oxygen, pH and turbidity indicate that within the mid-layer and surface of the water column directly over the seeps all measurements are of typical open coastal values (Smith Exhibit 19). As the water directly over the seeps would be further diluted with ambient seawater by the time it reached the shallow aggregate area of the reef where corals proliferate, there is no evidence that alteration of water quality from seep discharge could affect reef structure and function.

Dr. Smith discusses her work using the ratios of stable isotopes of nitrogen (the ratio of ^{15}N to ^{14}N, which is expressed as $\delta^{15}N$) to "distinguish between natural and sewage-derived nitrogen." However, as stated by Soicher and Peterson (1997) "principal agricultural activities in the area of sugarcane and pineapple culture contributed elevated loads of nutrients and sediment to coastal waters." In a comparison of major nutrient sources to groundwater, these authors estimated that in 1995 approximately 61.5% of the nitrogen in groundwater of West Maui was from agricultural and golf course inputs compared to 29.8% from wastewater injection. Only 8.7% was attributed to natural background "forest" input. While it is likely that agricultural input has lessened in recent years owing to closure of the sugar and pineapple plantations, residual materials in the soil still probably leach to groundwater. As a result, it is inaccurate to state that studies on West Maui involving $\delta^{15}N$ serve to "distinguish between natural and sewage-derived nitrogen" when the formerly largest contributor of nitrogen to groundwater was clearly not a "natural" source.

This argument becomes even stronger when the $\delta^{15}N$ signatures from the various sources of nitrogen are examined. Exhibit 45 is a chart showing the range of values of $\delta^{15}N$ from various sources (Bedard-Haugh et al. 2003). It can be seen that while the values for sewage material is elevated to a range of ~+20, fertilizer nitrogen is approximately zero, equivalent to the value of nitrogen in the atmosphere. Thus, regardless of the concentration of fertilizer nitrogen in a sample, it will have a $\delta^{15}N$ of near zero. Hence, even if the contribution of sewage

N is small in a sample with high fertilizer N, it will be interpreted that the sewage is the only contributor to the nitrogen pool based on ratios of stable N isotopes. For instance, in an area where discharge of groundwater subsidized with fertilizer nitrogen results in marine water concentrations of 10 μM, the δ^{15}N of plants grown in the area would be near zero. In a neighboring area where sewage subsidies to groundwater would result in marine water concentrations of 1 μM, the δ^{15}N would be a value higher than zero, giving the faulty impression that this area is receiving more nutrient loading. With it known that there is likely a significant contribution to West Maui groundwater from fertilizer sources, any study that does not take this into account is flawed.

The results of Dr. Smith's field stable isotope studies seem to be limited to the conclusions that marine plants take up nutrients discharged to the water column from the seeps. The finding that marine plants took up available nutrients simply supports the centuries old knowledge of all farmers and gardeners that increased levels of nutrients applied to plants makes them grow better. However, these results are somewhat suspect not only for the reasons stated above regarding the δ^{15}N of the contribution of fertilizer nitrogen, but also that the experimental set-up involved an artificial stationary placement of marine plants in settings where they do not naturally occur. Hence, extrapolation of the results to the natural environment is not valid.

The laboratory experiments, where various species of algae were exposed to elevated levels of sewage-derived nutrient also does nothing but confirm the basis for the fertilizer industry that addition of nutrients to plants makes them grow. This result is also the basis for the practice of re-use of treated sewage effluent for fertilization/irrigation of terrestrial setting where enhanced plant growth is desired. Unfortunately, an opportunity was lost in this experimental set-up to determine if there was a differential response by algae to nutrients from different sources. Had the experimental treatment included dosing plants with similar concentrations of nutrients from sewage, fertilizer, and natural groundwater, and determining if there were differential responses would the experiments been of worth.

1B4. Dr. Smith states that "the effluent emerging from the seeps must pass by/through the reef benthos before being mixed with surrounding seawater." There is no data to support this statement, and in fact all data collected to date indicate that this statement is incorrect. As stated repeatedly above, none of the data sets collected by HDOH, USGS, or GTS included sampling over the shallow aggregate reef area at any distance from the seeps. As a result, there is no data supporting the claim that measurements of water chemistry show vertical gradients of materials from groundwater seeping up through the shallow aggregate reef area where corals grow; data only exists for the seeps which are located in the shallow pavement area of the reef where corals are not expected to grow.

In addition, the GTS included a scuba diver survey which was conducted in July, 2012 to document all visual submarine springs from Honokowai Point to Black Rock. The goal of this survey was to provide the project with information regarding the locations and dimensions (length and width) of additional submarine springs spanning study area. The survey was conducted by two scuba divers swimming together, and scanning the ocean floor for emerging submarine discharge. The locations of all submarine springs and any other areas that showed evidence of submarine groundwater discharge, such as by the presence of shimmering waters (a varying refraction of light as seen when fresh and salt or warm and cold water mix; sometimes referred to as "schlieren"), were mapped. The surveys completed a total of 86 transects of various lengths from Honokowai Point to Black Rock, covering a combined distance of 20.8 km (12.9 miles).

The GTS reports that in general, the divers were not able to find submarine springs other than those near or in the locations of already identified submarine springs in the NSG and SSG used in the tracer dye-monitoring portion of the project. Exhibit

46 from the GTS showing the locations of springs identified by diver swims on the reef off of Kahekili Park. Note that no springs were identified seaward of the main seep groups located in the shallow pavement area. In this nearshore region of Kahekili Reef, a total of 289 visible submarine springs were identified. The sum total of all visibly flowing areas of individually measured submarine springs in the NSG was 2426.8 cm^2 or 0.243 m^2. The total of visibly flowing areas of measured submarine springs in the SSG was 838.8 cm^2 or 0.0839 m^2. The combined total area of visibly flowing submarine springs was 3265.6 cm^2 or 0.336 m^2. The total area of the submarine springs is equivalent to a square 23 inches on a side. Such an area does not constitute a substantial area of the Kahekili reef, and it occurs in the zones where corals do not occur.

The results of these surveys indicate there is no basis for the claim of Dr. Smith that there are seeps discharging through the reef benthos (i.e., living corals) before being mixed with surrounding seawater. In fact, all data indicate that there are no seeps in the reef zones where the predominance of living reef corals occur.

1.C. Dr. Smith states that in her opinion that the reef at Kahekili will not begin to improve for at least four years after all wastewater injection ceases. All of the reasons for this prediction are flawed. First, this projection is based on a supposed end result of "the areas around the seeps to look similar to the more "healthy" portions of the reef." As stated repeatedly above, and supported by all available data including Dr. Smith's, the area around the seeps have never, and will never look like the supposedly more "healthy" portions of the reef regardless of the extent of discharge from the LWRF. This is a result of the natural oceanic processes that prevent coral colonization in the shallow pavement zone where the reefs occur. In particular, the NSG occurs under intermittent sand deposits. As corals are not able to settle and grow on shifting sand, it is a certainty that this area will never look like the outer reef habitats where corals can grow regardless of the activities associated with the LWRF. Inspection of the entire length of the Kahekili reef reveals that in no area does corals grow up to the sand beach, nor does such a growth pattern occur anywhere else on open coastal areas of Hawaii. The notion that corals would grow up to the sand in a similar manner that they grow in the aggregate reef zones indicates a complete and total lack of understanding of reef structure and function.

The projection of recovery, based on estimated time for all LWRF effluent to move through groundwater is also flawed. As described above, all available data indicate that the extent of the seep discharge does not extend over the reef at present, and diver swims conducted as part of the GTS found no seeps in the zones on the reef where corals proliferate. Hence, there is presently no basis to expect any changes to reef structure and function with cessation of discharge from the LWRF.

In addition, while it is not disputed that there is a component of effluent from the LWRF in water emanating from the seeps, all available data indicate that the discharge is diluted greatly immediately following discharge to the water column. As an example, HDOH monitoring data indicate that total nitrogen (TN) in the water column directly over the seeps represents only 1% of the concentration of groundwater within the reef that emanates from the seeps. In addition to the documented dilution to near background levels, net transport of water from the seeps is not toward the offshore reef, but rather along shore over areas where corals do not occur. All of these factors point to the conclusion that while the seeps may be enriched with nutrients and other water quality constituents compared to ocean water, there is no basis to expect that this discharge is presently affecting coral communities. As Kahekili is only monitoring area on Maui that HDOH has delisted as impaired for all dissolved nutrients, it is apparent that seep discharge is not resulting in degradation of water quality. Hence, it is not a viable argument to suggest that eliminating the LWRF contribution to seep discharge will result in any detectable improvement to the status of water quality in the area.

In addition, the LWRF has been in continuous operation for approximately 30 years. While there have been improvements in methods and levels of treatment over this period, it is assumed that some fraction of the injected effluent has reached the seeps during the entire period of discharge. If effluent had been impacting reef structure and function continuously for three decades, it would be apparent by clear gradients of damaged or dead zones across the reef marked by increasing levels of dead coral and high algal cover with proximity to the seeps. However, all data from all sources (CRED/DAR, CRAMP, our work) reveals that there are no such gradients. In fact, CRAMP data indicates that there has been increases in coral abundance from 1999 to 2012. No macroalgae that has intermittently caused bloom conditions over the past decades has appeared on the reef over the last 7 years.

All of this information sums up to the conclusion that there is no evidence that effluent material emanating from the seeps has any determinable effect on coral community structure and function. With no such determinable effect, it is not valid to project recovery, as there is nothing to recover from.

EXHIBIT 2.

The interpretation of the photos shown in Dr. Smith's Exhibit 2 are also erroneous and misleading. The statement that the coral in the left hand frame (A) represents a landscape view taken across the reef, while center frame B is an "up-close view of a portion of the reef shown in A" is incorrect as the corals in the two photos are not even the same species. While the center photo does show cyanobacterial growth in the interstitial spaces of a stand of *Porites compressa*, the corals in A are *Porites lobata*. Hence, the two photos are clearly not the same portion of reef. Anyone not able to distinguish between these two species, which are the two of the most common species on most Hawaiian reefs cannot call themselves an expert on Hawaiian reefs.

There is also no documentation of how large a part of the reef that the "overgrown" areas occupied. Nor is there any mention of how common these overgrown patches were across the reef. And most importantly, there is no discussion of whether there was a documented gradient of increased cyanobacterial and turf growth with respect to proximity to the seeps. As cyanobacteria are a normal component of all marine environments, a photograph documenting such presence has no relevance regarding the cause-and-effect relationship. The coral species shown in frame C, *Porites compressa* typically grows in interconnected lattices with only the branch tips containing living tissue. There is no evidence in frame C that the branch tips are being overgrown or "engulfed" by turf algae. Also, there is no "fleshy" macroalgae visible in this photograph, but rather what would be classified in the CRED/DAR system as "turf-bare" cover between the living branch tips. The lack of fleshy algae suggests that it is more likely that the growing coral branch tips are expanding on the coral lattice framework that may have been damaged by a previous episode of stress that killed part, but not all of the corals.

EXHIBIT 4

The four photographs in this Exhibit show various areas of the reef at Kahekili with various types of algal cover. However, it is clear that the 2014 photo is of a completely different area as the other photos. The 2014 photo is of the nearshore shallow pavement where corals do not occur, and water depth can be seen to be only a meter or less. However the 2001photo showing a diver indicates that the water depth is at least 2-3 meters indicating it is not on the shallow reef pavement. The three photos showing dense aggregations of macroalgae are dated 2001, 2003 and 2004 indicating that the photos are 11-14 years old. The lack of photos showing macroalgal infestation in more recent years indicates that such blooms have not taken place for more than approximately a decade, during which time the LWRF operated continually. In addition, there is no indication of the location of any of the photos relative to the two seep areas, or even if the seeps had been identified at those points in time. As a result, these photos have no bearing on any relationship with occurrence of algal blooms and discharge from the seeps.

EXHIBITS 5 and 6.

The caption for Exhibit 5 is misleading as the right hand image is not the same colony as the left and center, so it does not show "gradual overgrowth and mortality of the coral by turf algae competition." In addition, the coral in the right hand frame exhibit signs of "pink line syndrome" which is a coral disease that is routinely observed in a small fraction of corals (primarily *Porites lobata* and *P. lutea*) throughout Hawaiian reefs. No information is provided on where the photographs were taken, nor the proximity to the seeps. It is also stated in the caption from Ross et al. (2012) that a 25% loss of tissue occurred in a 3-month period from August to November 2011. If this rate of loss was linearly extended the entire colony would be overgrown in a 12-month period. The LWRF has been in operation for approximately 30 years with continuous discharge of effluent to groundwater. In the photo in Exhibit 5, the coral colony was apparently in a healthy condition in August 2011. It is not plausible that the so called overgrowth and mortality of the coral could suddenly occur as a result of seep discharge following decades of seep discharge with no apparent effect. Examination of Ross et al. (2012) makes no mention that their work documented cause and effect of seep discharge and algal overgrowth. So implying that the photos in Exhibit 5 do so is not valid.

Similarly, the conclusions presented in Dr. Smith's Exhibit 6 are unfounded. While there is algal overgrowth in these close-up photos, there is no indication of the abundance or rarity of such occurrences, where they occurred on the transects, or whether they occurred in any kind of gradient with respect to distance from the seeps. In addition, most of the coral tissue under the algae is still living, indicating that the overgrowth is recent. Thus, the algal overgrowth would have had to have occurred relatively soon before the picture was taken in July 2014.

As the LWRF has been in operation for approximately 30 years, it would be expected that if it is indeed causing damage to corals, such damage would have completely decimated the reef decades ago. The fact that the corals in Exhibit 6 are all alive indicates that any factors responsible for the overgrowth would be of a recent occurrence and not one that has persisted for decades. In fact, the summer of 2014 in Hawaii was anomalously warm with an absence of tradewinds, resulting in significant bleaching events at many shallow reef locations in Hawaii. Such thermal stress is a far more likely factor to result in some degree of algal overgrowth. In any event, the photographs in Exhibit 6 cannot validly represent impact originating from the submarine seeps.

EXHIBIT 16.

This photograph shows an area of *Porites compressa* with cyanobacteria growing in the interstitial spaces between living branch tips. There is no indication of the density of such growth over the reef, or if this area is common or rare. In addition it is stated that the living coral is "within the north seep group." As the north seep group occurs primarily in a sandy area (Appendix B), it is not likely that this photo is from anywhere near the actual north seep group. Also, while there is cyanobacteria present, much of the coral colony remains alive, and portions of it in the edges of the photo appear healthy and undisturbed. If this coral actually occurred within the north seep group, and the seep discharge had an effect on coral from overgrowth by turf algae, it is not likely that after 30 years of discharge from the seeps, there would be any living portion of the colony. Instead, only a small portion of what appears to be a large coral colony is affected by cyanobacteria. This effect could not reasonably be a result of seep discharge.

2. EXHIBITS THAT WILL BE USED TO SUMMARIZE OR SUPPORT OPINIONS

Exhibits 1-46 below, Exhibit 47 (Appendix A) and Exhibit 48 (Appendix B), included with this report, as well as excerpts from the documents listed in Part 3.

3. DATA AND OTHER INFORMATION CONSIDERED IN FORMING OPINIONS

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4. WITNESS QUALIFICATIONS, INCLUDING A LIST OF PUBLICATIONS AUTHORED IN THE PREVIOUS TEN YEARS

(also see attached CV)

My qualifications to present these responses are based on both academic credentials and professional experience. In 1975 I received a Master of Science degree in Oceanography from the University of Hawaii. The subject of this degree was the first documentation of the environmental stresses that dictate coral reef community structure on Hawaiian Reefs. Several peer-reviewed journal articles have been published describing this work which still stands as the cornerstone model of coral reef structure in Hawaii, including the reefs off Kahekili Beach. In addition I have conducted over 100 professional assessments of coral reef communities in the Hawaiian Islands and other Pacific Islands to document how both natural and anthropogenic (caused by humans) stresses affect coral reef structure and function. In 1986 I received a PhD. degree in Oceanography from the University of Hawaii. The subject of this work was to document the effects to nutrient dynamics between the sea floor and overlying water column resulting from discharge of sewage from the two large municipal ocean sewage outfalls off of Oahu. Since this time I have conducted numerous professional studies of the effects of nutrient subsides to the ocean from sewage input as well as other natural and anthropogenic sources, particularly those associated with land uses involving application of fertilizers. Of particular relevance is that I presently conduct monitoring programs for compliance with NPDES permits for privately operated and municipal ocean sewage discharges off of Oahu, Kauai and the Island of Hawaii. These monitoring programs involve ongoing periodic collection and analyses of water samples to determine effects to water chemistry from the effluent discharges, as well as ongoing benthic monitoring programs to determine the effects of sewage discharge to reef environments in the vicinity of the ocean outfalls.

An additional foundation for the information in this declaration comes from data that I collected and published in a report in 1997 to the US Dept. of Commerce, NOAA Coastal Oceans Program and the State of Hawaii Dept. of Health entitled "Algal Blooms off West Maui: Assessing Causal Linkages Between Land and the Coastal Ocean" (Dollar and Andrews 1997). It is of note that the first identification of the nearshore seeps that are the subject of this declaration occurred in 1995 during the course of fieldwork for this report. My opinions are also based on a site visit to the area of concern in West Maui conducted on April 4, 2014 as well as a field survey that included quantifying reef community physical and biotic structure as well as evaluating marine water chemical composition of the area. These surveys extended from the sand beach shoreline out to the limit of coral growth.

My present employment is as a Coastal Resources Specialist in the School of Ocean and Earth Science and Technology, and as the President of Marine Research Consultants, a private consulting group operating in Hawaii since 1978.

As a result of this professional training and experience over the last 38 years, I have a uniquely suited background to address the environmental effects to the marine environment resulting from discharge of the Lahaina Wastewater Treatment Facility.

5. LIST OF ALL OTHER CASES IN WHICH, DURING THE PREVIOUS FOUR YEARS, THE WITNESS TESTIFIED AS AN EXPERT AT TRIAL OR BY DEPOSITION.

No other cases.

6. STATEMENT OF THE COMPENSATION TO BE PAID FOR THE STUDY AND TESTIMONY IN THIS CASE.

Expert will be paid $200 per hour worked for all services.