Environmental Defense Sciences

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EXPERT REPORT

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Hawai'i Wildlife Fund, *et al.*, v. County of Maui, CIV. No. 12-00198

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1. Introduction

The purpose of this expert report is to analyze and review available data regarding the discharge and impact of the treated wastewater injected into the ground at the Lahaina Wastewater Treatment Facility (LWRF), and to specifically opine upon the fate of effluent injected at Wells 1 and 2. The report addresses in particular claims regarding the sources, transport and impact of nutrients, acidity, salinity, dissolved oxygen (DO) and temperature on near shore coastal waters that could result from effluent injection and relates these factors to effluent injected at Wells 1 and 2. This report also addresses the plaintiffs' expert, Dr. Moran's, opinions, as expressed in her Expert Disclosure Report in this case dated October 6, 2014, that wastewater injected into Wells 1 and 2 over the past seven years was transported to the nearshore ocean along similar flow paths as wastewater injected in Wells 3 and 4, travelling at a similar rate of flow and entering the nearshore ocean at a similar concentration.

The opinions expressed in this report rely extensively upon published documents describing the hydrogeology of West Maui and, in particular, details of investigations of the plume of injected LWRF treated effluent described in the *Final Interim Report* (Glenn *et al.*, 2012) entitled Lahaina Groundwater Tracer Study-Lahaina, Maui, Hawaii, and the similarly titled *Final Report* (Glenn *et al.*, 2013)[1]. While these reports are primarily devoted to describing the results of a tracer study in which dyes (fluorescein [FLT] and rhodamine [SRB]) were injected into injection wells located at the LWRF, they also include a substantial amount of other information concerning the measurement of certain elements and ions in the effluent, in a number of production and monitoring wells, and in submarine springs (SS) and ocean waters in the near shore region of the Kaanapali coast. While certain water quality parameters and other attributes of the springs were measured in this study almost daily for an extended period (*e.g.*, pH, temperature, conductivity, and fluorescence), other data, such as nutrients in the spring water, wells and near shore waters, were only measured on two occasions, namely in June and September of 2011. These limited chemical data related to nutrients make the interpretation of the nutrient concentrations and fluxes from the springs and seeps somewhat problematic. For this reason additional water sampling data collected by the Hawaii Department of Health (HDOH) during the period 1/25/2012-7/14/2014 form an important resource in the analysis of the LWRF effluent plumes and how they relate to the plumes from Wells 1 and 2.

The basic difficulty is that, as shown by other USGS studies of the SS in 2010 (see Swarzenski *et al.*, 2012, Figure 11), the spring water salinity is highly correlated with the tide, the maximum occurring at high tide. The correlation of nutrient concentrations with the tide is not directly known, except that the

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[1] In the following we refer to these two documents as *Interim Report* and *Report*, respectively.

monthly data from the HDOH sampling program appears to show that nutrient concentrations in the spring water are related to low salinity. Furthermore, as shown in Figure 13 of Swarzenski, the flux of radon gas from the primary submarine groundwater vent site (representative of the flow rate of water from the spring) is also correlated with tide, but with the maximum occurring at low tide, at which time the hydraulic gradient available to drive the springs is at a maximum.

These findings by the USGS study are important because the samplings of the springs in the Glenn *et al.* studies appear to have been done at random times and at different times at different submarine seeps. Thus obtaining a definitive picture of the concentrations and fluxes of nutrients from the Glenn *et al.* sampling program is not without significant risk.

Since there are no data that directly relate the effluent injections at Wells 1 and 2 to the ocean, opinions about the fate of the effluent from these wells must be based upon knowledge of how flows move in aquifers, coupled with a detailed examination of the fate of effluent from Wells 3 and 4, which therefore forms a significant part of this report.

Section 2 of the report, immediately following, provides a complete statement of all opinions I will express. Section 3 details the basis and reasons for my opinions and the facts and data I used in forming the opinions. Section 4 presents the exhibits I use to support my opinions. Section 5 details my qualifications, including a list of all publications authored or coauthored. Section 6 provides a list of all other cases I have testified at trial or by deposition for the last four years. Section 7 provides a statement of the compensation to be paid to me for the study and testimony in this case.

2. Complete statement of all opinions the witness will express

2.1 No pollutant from LWRF Well 1 has been traced to the ocean.

- To the best of my knowledge, no tracer study has ever been performed on Well 1.

2.2 No pollutant from LWRF Well 2 has been traced to the ocean.

- Independent tracer studies on Well 2 by Tetra Tech and University of Hawaii were unable to detect unequivocally the injected tracer in the nearby coastal waters, The University of Hawaii concluded in its Report that “no conclusions can be made regarding the connection between Well 2 and the nearshore waters at Kaanapali” (also known as Kahekili Beach) (*Report*, p. 4-39).

2.3 Any flow from the LWRF wells to the ocean disperses broadly and diffusely through an unconfined aquifer and, therefore, groundwater in this case is not a confined and discrete conveyance.

- LWRF treated effluent is injected via four injection wells into a high hydraulic conductivity (500-900 ft/day) unconfined aquifer between 60 ft and 210 ft. below ground surface (BGS) at a current average annual rate of 2.8 million gallons per day (mgd). The saltwater interface at the base of the freshwater layer beneath the island (the Ghyben-Herzberg lens) is located between

85 ft and 115 ft BGS (Gingerich and Engott, 2012, Figure 13). The majority of the effluent is therefore diffusely injected into the salt water beneath the site through well screens or open boreholes that span 100 ft or more in depth (Exhibit 2) .

- The aquifer is comprised mostly of puka rock (*i.e.*, rock with small holes) and is fed by infiltration on the Wahikuli watershed. The natural flow within the aquifer is toward Kahekili Beach and is driven by a hydraulic gradient derived from the pressure of water that has infiltrated at higher elevations inland. Effluent injected into the groundwater aquifer is significantly less dense than the underlying salt water into which it is injected and it is therefore buoyant and will rise and float on the salt water, mixing with the natural aquifer flow and salt water as it moves toward the coastline driven by the hydraulic gradient. The flow pattern is appropriately depicted in a general way in **Exhibit 12** (Figure 28 from Hunt, (2006)).
- Based on the overall average flow velocity and the thickness of the aquifer the plume of injected effluent from all four wells will be diffuse and in excess of 800 m wide at the shoreline, thus forming a broad intersection interface with the coastal waters, as depicted in **Exhibit 11** (Figure E3 of Hunt and Rosa (2009)).
- The location of Wells 1 and 2 upstream of Wells 3 and 4 means that the effluent injected at Wells 1 and 2 will lie on the lateral boundaries of the plume from Wells 3 and 4. Modeling in the *Report* shows that effluent from Well 2 will only appear at the SS if Wells 3 and 4 are not operated and will also appear further up the coast away from the SS. However, for the last seven years up through July 2014, both Wells 3 and 4 have been operating, except for Well 3 in November 2013, and thus, any discharge from Well 2 would not have appeared at the SS, as has been described for the effluent from Wells 3 and 4 in the *Report*. There was no modeling done on Well 1 in the *Report*.
- Analysis of the possible flow fields from Wells 1 and 2 with Wells 3 and 4 in operation shows that the effluent injected at Wells 1 and 2 will be widely dispersed. **Exhibit 10**, developed from the theory of groundwater flow, shows that effluent injected at Wells 1 and 2 will be pushed to the lateral boundaries of the effluent plume when Wells 3 and 4 are operating. This basic result is confirmed by modeling results presented in the *Report* for Well 2 (see p. 4-90). The longer path from Wells 1 and 2 to the shoreline will mean extra time will be required for the effluent from these wells to reach the coast.
- The presence of the north and south spring groups at the interface of the plume with the coastline does not mean that there is not a broad seepage interface with the coastal waters. The springs, found to be driven by geothermal activity (see discussion below), discharge a small fraction of the total groundwater discharge, "ca. <10% of total groundwater discharge, with diffuse groundwater discharge constituting the rest.", (*Report*, p. ES-2). **Exhibit 14** summarizes data from the *Report* and has been prepared to put into perspective the springs and their flow rate with respect to the overall estimated diffuse flow where the effluent is dispersed into the coastal waters. It is apparent that effluent from Wells 1 and 2 enters the ocean outside the diffuse seepage area because the tracer injected in Well 2 was not identified.
- The springs occupy a very small area (less than 0.34 sq. meters) and discharge less than 400 m^3/d so that even if the springs were 100% effluent they would represent a tiny fraction of the effluent flows (~10,000 m^3/d) and the remainder must enter the ocean as a diffuse flow. As shown in **Exhibit 10** and Figures 4-39a and 4-39b of the *Report* (p. 4-90), effluent from Wells 1 and 2 forms part of this diffuse flow.
- There is no conclusive evidence that the effluent from Injection Wells 1 and 2 reaches the ocean in concentrations that enable the specific identification of the effluent from those two wells. In other words, the effluent distribution into the ocean from these wells is so diffuse that

it cannot be uniquely identified. With no discernible discharge point for the effluent injected into these wells it is difficult to see how an NPDES permit could be issued or, if issued, monitored for compliance as the point of discharge has not been identified.

2.4 Multiple other sources add pollutants to groundwater in the West Maui watershed.

- High concentrations of nitrate and phosphate are present in upland wells that monitor the groundwater flow in West Maui and in the Wahikuli watershed.
- These concentrations are most likely residuals of agricultural practices in the pineapple and sugarcane plantations formerly in the area as well as fallow corn and coffee and active coffee growing operations.
- Landscaped areas around resorts, residential properties and golf courses in the West Maui watershed are likely sources of nitrogen and phosphorus to groundwater and coastal waters either from the use of reclaimed water from the LWRF or fertilizer application.
- The groundwater passing through the basaltic lava aquifer likely accumulates phosphates, such as has been identified elsewhere where similar volcanic aquifers occur (Lynn, 2005).
- Surface runoff has also been identified as a significant source of nutrients to the coastal waters and periods of very high intensity rainfall result in high transport of nutrients in both surface streams and infiltration.
- The effluent plumes from Wells 1, 2, 3 and 4 are therefore neither a discrete nor unique source of nutrients to the coastal ocean since the effluent injected into the aquifer using Wells 1, 2, 3, and 4 must comingle within the aquifer with other sources of nitrate and phosphate. The effluent mixed with other sources therefore cannot form a discrete and discernible discharge to the ocean.
- Other data from HDOH suggest that the total nitrogen (TN) and nitrate concentrations in the springs are highly variable.
- According to the data presented in the *Reports*, the total phosphorus (TP) concentration of the SS water is roughly between 2 and 3 times the concentration of TP in the effluent. The source of this additional phosphorus is not immediately evident. However, HDOH data suggest that the average phosphorus concentration in the springs may be slightly less than that of the effluent.
- The concentration of magnesium in the SS water is between 2 and 5 times that in the LWRF effluent. In addition, the measured chloride and sulfate concentrations of the SS water are roughly between 3 and 15 times that of the LWRF effluent.
- It is therefore evident that the SS springs are not simply undiluted LWRF effluent and must contain water and elements from other sources.
- Since the aquifer material (basalt) is known to contain very little chloride the SS water must contain a significant fraction of sea water, as there is apparently no other source for the chloride in the SS water as water in upland wells and effluent are low in chloride.
- Sea water also contains a high concentration of magnesium and sulfate so the elevated levels of magnesium and sulfate in the SS water confirm that the higher salinity of SS water is a result of mixing with some seawater.
- Sea water is low in phosphorus content so there must be some other phosphorus source to provide the elevated phosphorus concentration in the SS water. The injected effluent has an average TP concentration of 562 μg/l, of which approximately 50% is phosphate (PO_4^{3-}). By

contrast the seeps have total phosphorus content of 350-468 μg/l, of which about 80-90% is phosphate; clearly phosphate is being supplied within the aquifer.

- Possible sources of phosphate are phosphorus containing minerals (*e.g.*, olivine) in the basaltic lava aquifer, which is known in other locations to have phosphorus content in the range 0.3-1.3% that leaches into groundwater.
- Another possible source of phosphorus is groundwater from upland regions within the historical sites of pineapple and sugar cane plantations.
- TN and nitrate levels in the SS water are much less than the concentrations of TN and nitrate at Black Rock Lagoon, located to the south of the springs. The phosphorus levels in the SS water are of the same order as those at Black Rock. The claim of "exceptionally elevated" nitrogen and phosphorus concentrations near the seeps has no basis in the data presented in the *Report*.
- Although the submarine ground water discharge at Kahekili Beach provides an estimated 16 percent of the groundwater inflow to the coastline between Hanakao'o Beach and N. Honokowai, it provides only between 2 and 4 percent of the dissolved inorganic nitrate (DIN). The submarine springs therefore cannot be recognized as a significant source of DIN to the coastal waters.
- Although discharge to the ocean from Wells 1 and 2 has not been identified, based on the analysis of the effluent from Wells 3 and 4, we can conclude that the peak concentrations of nutrients from Wells 1 and 2 are likely to be significantly reduced because of the diffuse nature of the discharge. This conclusion is supported by HDOH measurements of nutrients in the nearshore zone.

2.5 The Reports' and Plaintiffs' analysis and conclusions regarding certain Tracer Study parameters are faulty.

2.5(a) Acidic waters

- A statistical analysis of pH data shows that the mean pH of water <u>within</u> the springs has an average of between 7.35 and 7.69 (*Report*, Table ES-1).
- The pH at the <u>nearshore</u> ocean sampling points M-1 through M-34 was between 8.07 and 8.14 (*Interim Report*, Tables 6-5 and 6-6).
- By contrast, the three control Stations (Honokowai Beach Park, Wahikuli Wayside Beach Park and Olowalu, see Table A-5 of *Report*) had an average pH of 8.05 with a standard deviation of 0.08.
- The waters <u>near</u> the SS have a pH that is statistically indistinguishable from the control stations and there is no foundation upon which to claim that water <u>near</u> the seeps is substantially more acidic than the rest of the ocean's nearshore water.
- If Wells 3 and 4 are not in operation then any discharge from Wells 1 and 2 to the ocean will have similar properties and any impact on the nearshore pH will be confined to the immediate vicinity of the springs as it seems likely that if Wells 3 and 4 are not operating the plume from Wells 1 and 2 could overlap the springs (see **Exhibit 10** and Figure 4-39b). (Note, however, that in Figure 4-39b Well 2 injectate is predicted to flow north as well.) If Wells 3 and 4 are in operation the impact of Wells 1 and 2 on the nearshore pH will be undetectable.

2.5(b) Salinity of seeps

- All rainwater that falls on an island and infiltrates either flows off the land as surface streams or emerges at the shoreline as groundwater submarine springs and diffuse flow.
- The existence of submarine freshwater springs at Lahaina has been known for a very long time and they will persist as long as rain continues to fall on the island.
- Groundwater is by nature lower in salinity than seawater and any salinity in the seeps can only be attributed to the seawater driven upward by geothermal activity beneath the springs.

2.5(c) Dissolved oxygen

- The DO concentration in the injected effluent is of the order of 6.9±0.3 mg/l.
- If all the HDOH ocean sampling data are reviewed the average DO concentration at control stations away from the springs is between 6.1 mg/l (north control) and 6.9 mg/l (south control).
- The average of 27 months of data shows that the DO within the water column immediately above the springs is 6.4 mg/l, which is within the control station DO levels.
- The HDOH data show that the DO of waters within the springs averages 5.1 mg/l, which is far from anoxic. The fact that the DO concentration within the springs is lower than in the injected effluent is likely due to consumption of oxygen by oxidation processes within the aquifer, which are common.
- Any effluent injected from Wells 1 and 2 will likely be subjected to the same reduction in oxygen concentration but, as observed in the HDOH ocean samplings, this is of no consequence to nearshore waters.

2.5(d) Water temperature

- Temperature variations from 23.8 °C (7/29/2011) to 35.9°C (9/18/2011) [73.8°F -96.6°F] were recorded in Seep 6. In some cases temperatures changed by as much as 5°C (9°F) within a day (Seep 6 on 8/6/2011 between 9:20 am and 3:30 pm.)
- These rapidly fluctuating and elevated temperatures cannot be ascribed to either exothermic heating or effluent temperatures because of (a) insufficient biochemical energy available and (b) lower effluent temperatures and (c) the thermal inertia of the aquifer smoothing any fluctuations in injected effluent temperature.
- Wastewater effluent is not responsible for any thermal anomalies measured in the nearshore coastal waters at Kahekili Beach. This temperature anomaly is of natural geothermal origin.
- The geothermally-driven mixing of seawater and other waters explains the elevated concentrations of magnesium, chloride and sulfate in the spring waters and the fact that the concentrations of these constituents and the temperature fluctuate, as is common in geothermally-driven convective plumes in aquifers.
- It is likely that the gas emitted from the springs has a geothermal origin. Hydrothermal springs very commonly have bubbles rich in nitrogen, argon and carbon dioxide, all gasses that were measured in the springs (*Interim Report*, Table 6-11 p. 192).
- The nitrogen gas emitted in the springs has a δ^{15}N of zero, indicating that it likely did not arise from denitrification of effluent nitrate as claimed in the *Report*.

- The spring waters have high concentrations of radon and radium isotopes that commonly occur in geothermal springs. Given the short half-life of these isotopes and the relatively long horizontal travels time for water in the aquifer there must be a local source for these isotopes immediately below the springs.
- The geothermal potential in the Lahaina area has been noticed in previous studies.
- Using salinity and temperature data it is estimated that geothermally driven flow probably contributes 11% seawater to spring flow during a temperature excursion and that the specific spring flow analyzed is likely to have about 40 per cent effluent and 50 percent upland fresh water. Note that this is not the estimated fraction of effluent in the submarine groundwater discharge (SGD), just the fraction of effluent in the specific springs analyzed. It is also noted that the springs are estimated to contribute less than 10% of the SGD flow to the Kahekili Beach area, which implies that at least 90% of the effluent must be distributed to diffuse seepage flow.
- It is unlikely that effluent from Wells 1 and 2 will be influenced by these localized geothermal flows and any effluent from Wells 1 and 2 will not contribute to this thermal anomaly. As shown in **Exhibit 10** the flow path for the effluent injected at Wells 1 and 2 is very likely outside the range of the geothermal springs and therefore cannot participate in the thermal anomaly.

2.5(e) Dilution of effluent

- Dilution of the spring discharges within the coastal water is initially generated by their buoyancy producing a vertical plume in the ocean above the spring. The intensity of the mixing can be determined from the measured concentrations of radon and silicon within the spring and at the water surface above the spring.
- If there is zero concentration of the tracer (radon or silicon) in the entrained diluting water then the dilution is simply the ratio of the concentration in the spring to that measured at the surface. However, there is both radon and silicon in the ambient seawater that provides the dilution and this must be accounted for.
- Spring dilutions calculated based on minimum ambient silicon levels indicates immediate spring dilutions exceed 40. Spring dilutions based on average radon concentrations, and a high estimate of ambient concentration (*i.e.*, a conservative estimate), are in the range 20-50.
- Dilutions in this range explain why the salinity, pH, nutrients and DO levels in the surface waters above the springs are statistically no different from the ambient seawater.
- Effluent in the diffuse seepage zone cannot be identified by any measured parameter such as pH, DO, temperature, salinity, or nutrient concentration. Tracer dye concentrations in the diffuse seepage zone were almost a factor of 10 less than in the springs, indicating a high rate of dilution and a diffuse entrance to the ocean.
- Any effluent discharged from Wells 1 and 2 will be similarly diluted.

2.5(f) Flow dynamics in the ocean

- The seep water is discharged having a lower density than the ocean water and forms a rising plume that is diluted by the entrained ambient water. The dilution reduces the density difference between the seep water and the ocean.

- The small residual density difference will cause the diluted seep water to float near the ocean surface if there is a low wind and wave climate and the diluted effluent will be carried away by ocean currents.
- If the wind and wave climate is high the surface plume will be rapidly mixed into the water column and transported out of the area by the alongshore currents.
- The dilution and transport of the effluent in the seeps is so effective that the Kahekili Beach is proposed for delisting by HDOH as an impacted coastline for nutrients.

2.5(g) Fraction of LWRF in the SGD

- The fraction of LWRF effluent in the total SGD within the North Seep Group (NSG) and South Seep Group (SSG) areas was estimated in the *Interim Report* and the *Report* using two methods: a tracer dye break through curve (BTC) analysis (64% of injected effluent discharges as springs and diffuse flow and 68% of total groundwater discharged in SGD is treated effluent) and a geochemical/stable isotope analysis (62% effluent in SGD). There are significant uncertainties in both analyses and some assumptions used in the two analyses are either flawed or difficult to justify. The issues are summarized below.
- The FLT dye concentration was measured at a very limited number of springs, which covered less than 1% of the area of the NSG and SSG. It is likely that the measured dye concentrations cannot represent dye concentrations of all springs, especially springs in the NSG where dye concentrations measured during a survey were distributed over a relatively large range.
- The FLT dye concentration of the diffuse discharge was significantly lower (<15%) than that of the spring discharges. Thus, the BTCs derived from spring discharge dye concentration data should not be applied to the diffuse discharge.
- The dye recovery rate calculations in the *Report* used the spring discharge BTCs and the total SGD (*i.e*., spring discharge and diffuse discharge combined). Thus, the calculations very likely overestimated the dye recovery rate and the derived LWRF effluent fraction in the SGD is not meaningful.
- Constant fresh groundwater discharge rates were used in the *Report* to calculate dye recovery rate. However, data clearly show large (>70%) temporal variations in fresh groundwater discharge rates.
- Inconsistent salinity values were used for the FLT fraction in Equations 4-1 and 4-3, which are the bases for the evaluation of the FLT in the springs and SGD in the *Report*.
- The significant uncertainties in the dye recovery rate calculations warrant further analyses to quantify the uncertainty, which the *Report* failed to provide.
- Results from calculations with significant uncertainties are usually provided as a range of values rather than a single number. To serve as an example, alternative but plausible assumptions were used and it was found the calculated dye recovery rate was 11%, and the LWRF contributed 12% of the total SGD at the NSG and SSG areas.
- In the geochemical/stable isotope mixing analysis, half of the calculated data sets failed to provide any meaningful results, demonstrating that the geochemical/stable isotope analysis method is not reliable. In addition, only six samples were collected from four submarine springs, a data set that is far too sparse to cover the spatial and temporal variations of the total SGD.

3. Basis and reasons for the opinions and the facts and data used

3.1 Discharges from Lahaina Wastewater Reclamation Facility

The LWRF has injected treated wastewater into the ground since 1979, when injection Wells 1 and 2 were constructed. In 1985, Wells 3 and 4 were added as part of an LWRF expansion project. The locations of the four injection wells in relation to the shoreline are shown in **Exhibit 1**. The injection flow rate has varied seasonally and the annual average discharge rate was around 3.4 million gallons per day (mgd) (12,900 cubic meters/day) in the period 2010-2012 and is currently 2.8 mgd, which is equivalent to an average discharge rate of 10,600 m^3/d. The driller's logs for the injection wells are shown graphically in **Exhibit 2** (Figure 1-4 of the *Report* p. 1-21) and details from the driller's log for Well 4 in **Exhibit 3**. The wells discharge into the fractured rock aquifer between approximately 60 ft below the surface and 210 ft below the surface, depending upon the well. Since the aquifer transitions from fresh to salt water between 85 ft and 115 ft below sea level, the effluent is mostly injected into salt water within the aquifer (Gingerich and Engott, 2012, Figure 13). **Exhibit 2** shows the borehole stratigraphy and well screening and it is apparent that the well injection is diffusively spread over 100 ft or more of open borehole or well screen. **Exhibit 4** has the record of monthly average well injections in the period 4/11-3/13.

All waters that infiltrate the soil on an island must ultimately find their way to the sea either in the form of stream flows or via SS and diffuse flow at the shoreline or within adjacent coastal waters. The presence of such freshwater seeps and springs in the coastal waters of islands is well documented. The effluent injected into the aquifer is no different in this respect; it must ultimately find its way to the sea.

To put the effluent flows in perspective it is instructive to review the hydrographic and aquifer features in the Wahikuli and Honokowai watersheds. **Exhibit 5** is reproduced from the Wahikuli-Honokowai Watershed Management Plan (WMP, 2012). It can be seen that the Kahekili Beach area receives drainage from the northern section of the Wahikuli watershed and that the watershed is crossed by a series of ditches that transverse it in a north-south direction. These ditches will serve to capture surface runoff and provide a conduit for infiltration to the groundwater aquifer. Furthermore, as is apparent in **Exhibits 6 and 7**, the area immediately to the east of Kahekili Beach is all undeveloped agricultural land where infiltration is effectively unimpeded. Although the average rainfall on this West Maui coastline is moderate, at times the intensity can be very high. For example, eight instances of 24-hour rainfalls over 4 inches, and as much as 12 and 15 inches, of rain have fallen since 2001 (Brock, 2012). Such high intensity rainfalls must lead to significant infiltration and surface water runoff carrying high loads of nutrients that have been used on the agricultural land (see Tetra Tech, 1993; Storlazzi and Field, 2008).

The aquifers in the region are shown in **Exhibits 8 and 9.** Inland from the coastline the aquifer is an unconfined basaltic lava with a high hydraulic conductivity where infiltration goes directly to the water table. Closer to the shoreline the basalt is covered by a sedimentary layer with a lower hydraulic conductivity than the basal aquifer. The lower hydraulic conductivity would allow some pressurization of the basal aquifer because of the head necessary to drive water up through the lower conductivity sedimentary cover. In this respect the basal aquifer beneath the sedimentary layer can be described as "confined", but confined by a conductive layer. (The usual definition of a confined aquifer presumes that it is covered by a layer of very low permeability, or an aquiclude. In this case the confining layer has a reduced conductivity from the layer below, but not significantly so.) The overlying sedimentary layer will have no effect on the lateral spreading of the plume, which will likely widen as the thickness of the freshwater flowing later thins down near the coastline. A drilling log from an injection well (**Exhibit 3**) shows the aquifer to comprise mostly puka rock (rough surfaced volcanic rock containing holes, *i.e*., puka) (see also **Exhibit 2**). According to the USGS (Gingerich and Engott, 2012) the aquifer porosity (volume fraction of voids) is between 0.1 and 0.2 and the hydraulic conductivity is in the range 600-900 m/d. Such a high hydraulic conductivity implies that small hydraulic gradients can produce significant groundwater flow velocities as the flow moves uniformly towards the coast. This conclusion is supported by the radon flux measurements shown in Figure ES-7 of the *Interim Report* (p. xxv), where it can be seen that radon fluxes are very uniform along the coastline except at the springs (see further discussion of springs below).

There have been a number of studies that have attempted to document the flow from the LWRF injection wells into the coastal waters. And while recent tracer studies by Glenn *et al.* (2011, 2013) have shown that effluent from Wells 3 and 4 is present in the coastal waters off Kahekili Beach, there are no data tracing discharge of effluent from the Wells 1 and 2 to the ocean.

First, apparently no tracer study has been performed on Well 1, so there are simply no data available to relate Well 1 effluent to the coastal waters. The effluent from Well 2 was spiked with rhodamine in a 1994 study by Tetra Tech, who inserted 100 ppb into the wastewater stream for 58 days. Tetra Tech was unable to show unequivocally the presence of this rhodamine in the coastal waters.

In 2011/2012, University of Hawaii researchers injected SRB for 18 hours into Well 2 at concentrations that varied from 2,000 ppb to as high as 38,000 ppb (*Report* , p. 4-30) but found no confirmed detection of the tracer in the coastal waters (*Report*, p. ES-1). As discussed later in this report, any effluent injected into Wells 1 and 2 will lie on the boundaries of the plume created by Wells 3 and 4 and will likely only appear at the springs if Wells 3 and 4 are not in operation. (Under this scenario, Wells 1 and 2 flow paths will also go further up the coast.) However, for the last seven years through July 2014, Wells 3 and 4 have been operational, except for Well 3 in November 2013. Thus, during this time, it is very unlikely any effluent from Wells 1 and 2 was discharged at the springs. As stated in the *Report* (p. 5-24), “The potential presence of other discharge locations [for the effluent] is supported by the lack of detection of SRB at the NSG and SSG.” The *Report* (p. 5-25) also states correctly, “To test the hydraulic conductivity between Well 2 and the nearshore, a second tracer test would need to be conducted with Well 2 as the primary injection well.” The *Report* could reach no conclusions regarding the hydraulic connection between Well 2 and the nearshore waters at Kaanapali (*Report*, p. 4-39). However, the data in Figure 2-11 of the *Report,* (p. 2-24), which show a correlation between very low SRB measurements and high FLT measurements in the springs, strongly suggest that there is no preferred flow conduit from the Well 2 to the submarine springs. If there were the SRB concentrations in the springs would be much higher.

Dr. Moran’s argument that the flow from Wells 1 and 2 would be similar to that from Wells 3 and 4 is undermined by the MODPATH modeling results presented in the *Report*, Figures 4-39a and 4-39b. Despite the limitations of the modeling discussed in the *Report*, it is clear from a comparison of these two figures that the predicted flow paths from Well 2 operating alone are substantially different from those from Wells 3 and 4, but in either case the effluent flow paths are widely dispersed along the coastline. There was no modeling done on Well 1 in the *Report.*

In summary, there is no conclusive evidence that the effluent from Wells 1 and 2 reaches the ocean in concentrations that enable the specific identification of the effluent from those two wells. In other words, the effluent distribution into the ocean from these wells is so diffuse that it cannot be identified. With no discernible discharge point for the effluent injected into these wells it is difficult to see how an NPDES permit could be issued or, if issued, monitored for compliance.

As previously discussed, the unconfined aquifer into which the LWRF effluent is injected comprises mostly puka rock with a hydraulic conductivity of 600-900 m/d. The local hydraulic gradient towards the coastline is of the order of 2-3 ft/mile, or about 0.0005. This means that, in the absence of any well injection, the average flow velocity in the pores of the aquifer is in the range 2-3 m/d (based on a porosity of 0.15) and it would effectively take, on average, 400-600 days for groundwater to travel the 1200 m from the point of injection to the shoreline.

Since the injected effluent in all wells is much less saline than seawater, and therefore less dense, despite being injected into the salt water layer it will float on the saline intrusion that forms the base of the Ghyben-Herzberg lens of fresh water beneath the island. The base of this freshwater lens is located at a depth of about 85 ft below sea level at the location of the injection wells (Gingerich and Engott, 2012, Figure 13). Upgradient from the injection wells the natural groundwater flow is towards the sea, as is described in the USGS publication that reviewed groundwater reserves in the Lahaina area (see **Exhibit 9**, Gingerich and Engott, 2012).

In order to get a better understanding of the dynamics of the plume of effluent from the injection wells a simple model can be constructed with Wells 1 and 2 represented by a single source and Wells 3 and 4 by another a single source, with these two sources located in a uniform groundwater flow. Wells 1 and 2 (and 3 and 4) are so close to each other the pairs can be regarded as single sources and the approximation is not of consequence in considering the general flow field. Mathematically, this is represented by a potential function, and the streamlines are given by constant values of the function, ψ, namely:

$$\psi = Uy + (Q_{12}/2\pi\varepsilon h)\arctan(y/(x+a)) + (Q_{34}/2\pi\varepsilon h)\arctan(y/x-a)),$$

Q is respective the flow rate of the injection wells, h is the thickness of the aquifer (assumed uniform), ε is the porosity of the aquifer, x is the horizontal distance from the source along the axis of the plume and y is the lateral distance from the plume axis, and 2a is the separation distance of the two sources.

Using this function we can plot the streamlines resulting from the operation of the injection wells. For simplicity we assume that the average injection rates Q_{12} and Q_{34} are equal and are 5000 m^3/day, that the aquifer thickness is 35 m and the porosity 0.15. The spacing of the two sets of injection wells (2a) is 172 m. The streamlines from this pattern of injection wells is shown in **Exhibit 10**.

The obvious result from this simple modeling exercise is that the overall flow pattern of the injected plume is very similar to that depicted in Figure E3 of Hunt and Rosa (2006), reproduced here as **Exhibit 11,** and also the three-dimensional simulation results shown in **Exhibits 12 and 13**. These two exhibits, which are reproductions of Figures 26 and 28 from the simulation of the Kihei injection wells performed by the USGS (Hunt, 2007), show graphically how the plume of injected effluent behaves in the groundwater flow. Although these two graphics represent the plume from injection wells at Kihei the plume dynamics depicted will be essentially identical at Lahaina.

The other obvious feature of the streamlines depicted in **Exhibit 10** is that the effluent from Wells 1 and 2 will lie outside the plume generated by Wells 3 and 4, which offers an explanation as to why the tracer in Well 2 was not observed. While it is recognized that this simple model of the injection wells is an idealization, in the sense that it assumes equal flows from each pair of wells, does not account for mounding of the effluent at the injection wells and assumes also that the aquifer is of constant thickness, it nevertheless incorporates the basic features of the flow field well enough to show the separation of the flow fields from the two sets of injection wells.

As described in the *Report*, tracer (FLT) injected into Wells 3 and 4 first arrived at the NSG 84 days later and 109 days later at the SSG. Peak concentrations of 22.5 ppb and 34 ppb occurred 306 days and 271 days after injection at the NSG and SSG, respectively. The average travel time was about 430 days, indicating an average groundwater flow velocity of about 2.2.m/d. These differences between the initial arrival time, the peak concentration arrival time and the average arrival time are typical of all tracer studies in aquifers and indicate that the flow path from the wells to the shoreline is broad and diffuse and no preferential pathway is necessary to provide the initial fast breakthrough of any tracer along the axis of the plume.

In summary, the plume of injected effluent will partially mix with some of the salt water below the freshwater lens, but will largely float on the salt water in a spreading layer that moves toward the shoreline at about 2-3 m/d, on average, although the initial front of any injected tracer plume will arrive on the plume centerline much faster. As can be seen in the exhibits, at the shoreline the plume will be at least 800 meters wide, forming a broad seepage interface with the coastal waters.

As shown in **Exhibit 10**, since Wells 1 and 2 are upstream of Wells 3 and 4 in the natural groundwater stream the effluent injected at these two wells will be on the lateral boundaries of the plume moving toward the coast. The effluent from Wells 1 and 2 will therefore only appear at the submarine springs if Wells 3 and 4 are not in operation and will, as do Wells 3 and 4, discharge to the ocean as a mostly diffuse flow. For the relevant timeframe covered by this case, Wells 3 and 4 have been operating, except for Well 3 in November 2013. The presence of the NSG and SSG within this interface does not mean that there is not a broad seepage interface with the coastal waters. The seep vents discharge such a small fraction of the effluent flow (according to *Report* Table 3.4, seep vents max. 300 m^3/d vs effluent *ca.* 10,000 m^3/d) the remainder of the effluent must be released into the ocean over a broad front since tracer (FLT) injected into Wells 3 and 4 was detected outside the springs only at very low concentrations and tracer (SRB) injected into Well 2 was essentially undetected.

The *Report* focused on the presence of effluent in the NSG and SSG, as if these springs were a consequence of the effluent injection. However, it will be shown below that the water in the spring groups is not undiluted effluent and contains other elements at concentrations not present in the effluent. The springs, which occupy a very small area (less than 0.34 sq. meters) and discharge less than 300 m^3/d, are congruent with the formation of localized geothermal plumes within the aquifer and are not a consequence of the effluent injection or the presence of any preferential flow pathway.

To put the SS and the overall SGD (i.e., spring discharge and diffuse discharge combined) into perspective **Exhibits 14 and 15** have been prepared from data in the *Reports*. **Exhibit 14** displays the relevant data (*Report*, p. 3-4) regarding the area of the actual identified springs in each spring group; it can be seen that these areas are really quite small, less than a third of a square meter in total area. Also included in the annotation is the measured flow from these springs and again the numbers, relative to the injected effluent flows (ca. 10,000 m^3/d) are very small, less than 4 percent at maximum. The tabulations also show the area encompassing the 283 identified springs (areas circumscribed in red) and these two areas total 2,300 m^2. By comparison the defined area over which the diffuse seepage was estimated using radon fluxes is much larger, totaling 10,180 m^2 (the areas encompassed by the black rectangles). The actual identified spring cross-sectional areas therefore represent less than 0.0032 percent of the diffuse seepage area. The area encompassing all of the identified springs is less than 23 percent of the defined diffuse seepage area. In summary, the actual springs are a very small fraction of the diffuse seepage freshwater flow, which is spread over a relatively large area.

The flow from the springs and the diffuse seepage area are put into further perspective by the annotations on **Exhibit 15**, which is a reproduction of *Report* Figure ES-8 incorporating data from the *Report,* Table 3-5a. First, it can be seen that the freshwater flow rate estimated to be discharged at Kahekili Beach is a relatively small number compared to other locations on West Maui. This may well be a result of the small areas defined for the radon flux estimates of discharge. As can be seen in **Exhibit 15** the small rectangles at the NSG and SSG do not completely encompass the areas of higher radon concentration. In any case, the total estimated freshwater flow over the seepage areas is seen to be significantly less than the effluent injected into the aquifer, again indicating that the injected effluent is widely dispersed along the coastline.

3.2 Multiple other sources add pollutants to groundwater in the West Maui watershed.

As discussed previously in Section 3.1, and illustrated in **Exhibits 5, 6 and 7**, the upland area to the west of Kahekili Beach in the Wahikuli and Honokowai watersheds was formerly an area of intense agricultural development for pineapples and sugar cane (see also *Report,* Figure ES-1). The residuals from fertilizer applied to those fields remains evident in the high concentrations of nitrate and phosphate in the well waters, as shown in Tables 6-8 and 6-10 of the *Interim Report* and partially excerpted in **Table 1**, below. The Wahikuli watershed's agricultural district includes a combination of fallow seed corn, sugarcane, and pineapple and active and fallow coffee; these past and present agricultural practices "significantly altered the landscape and impacted the hydrology of surface waters and groundwaters." , (WMP, 2012, p. 9). Since this ground water must flow to the coast the nutrients shown to be in this water must appear at the shoreline. Undoubtedly there will be some denitrification as the water bearing the nitrate travels through the aquifer to the coast and this is likely responsible for the elevated N15/N14 ratio in the shore waters, (Böttcher, 1990).

In addition, the springs contain high levels of phosphate, which also occurs in Black Rock Lagoon and in groundwaters sampled by Hahakea 2 well (see **Table 1** below). The use of reclaimed water on Kaanapali Golf Course and stored in a pond on the course (see **Exhibit 5**) would also clearly lead to groundwater with increased levels of nitrogen and phosphate nutrients. The ponds have an overflow culvert so any intense rainfall will lead to a discharge to the Black Rock Lagoon area, which may be the source of nutrients in Black Rock Lagoon. The source of the high phosphate levels in the spring seeps are a matter for conjecture as the fraction of phosphate to total phosphorus in the spring water, as described in the *Report*, is much higher than in the effluent, which indicates that there must be an additional source of phosphate. It seems likely that it may be the basaltic aquifer.

The Wahikuli watershed's urban district contains resort complexes, residential housing, commercial properties, and golf courses (WMP, 2012, p. 9). Maintenance of landscaped areas around resorts, residential properties, and golf courses are likely sources of nitrogen and phosphorus; the primary source of phosphorus is fertilizer application (WMP, 2012, p.10).

A nutrient mass balance study for West Maui was performed by Tetra Tech in 1993. This study identified surface runoff as an important coastal nutrient source. As reported in Brock (2012) there are infrequent but very high intensity rainfalls that occur in West Maui, as much as 15 inches of rainfall in 24 hours. Such high intensity storms lead to serious erosion on agricultural lands and the sediment carried to the coastline can have high levels of fertilizer and pesticide residuals. The transport of soil containing fertilizers and pesticides by flood waters is well documented in the Salinas and Santa Clara river valleys in California and runoff from the fallow agricultural lands east of Kahekili Beach can be expected to result in similar transport of sediments with residual nutrients, as is described in Storlazzi and Field, (2008).

The claim has been made, based upon the fraction of nitrogen stable isotope 15 (N^{15}) measured in (a) nitrate dissolved in the treatment plant effluent and (b) measured in the groundwater discharged from submarine springs and (c) in macroalgae grown in near shore coastal waters, that nutrients in the treatment plant effluent are responsible for the macroalgae growth. In particular, it has been asserted[2] that: 'water near the seeps has "exceptionally elevated" levels of nitrogen and phosphorus.' And that 'In particular, the area near the seeps has the highest levels of sewage-derived nitrogen "ever reported in the scientific literature".'[3]

To examine these claims the concentrations of dissolved elements and anions measured in the effluent, submarine spring water, upland well water and ocean waters, and reported in the *Interim Report* and *Report* and other literature, have been reviewed. **Table 1** below gives relevant sample concentrations taken from these reports. The locations referred to in the table are shown in **Exhibits 16 and 17**. Data from Cox and Thomas (1979), and unpublished data received from the University of Hawaii (2014) that describe the sulfate concentrations of the effluent and submarine spring waters, are also included. It is important to reiterate that the data from the *Interim Report* and *Report* represent samples taken on only two occasions in June and September 2011 and that from Cox and Thomas represents a single sample.

Table 1 – Samples of element and anion concentrations.

Sample Source	**Chloride Cl^- (mg/l)**	**Magnesium Mg (mg/l)**	**Total Phosphorus TP (µg/l)**	**Phosphate PO_4^{3-} (µg/l)**	**Total Nitrogen (µg/l)**	**NO_3^- (µg/l)**	**SO_4^{2-} (µg/l)[4]**
LWRF Effluent[5]	568-582	33-39	164-206	102-164	6061-7245	2641-3454	73-82
UPLAND MONITORING WELLS							

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[2] See Partial Summary Judgment Motion.

[3] This is actually a misquotation, as the Smith Declaration that is referenced states: "…with algae samples grown over freshwater seeps in Kahekili's nearshore waters containing the highest δ^{15}N values ever reported in the scientific literature."

[4] Sulfate data from University of Hawaii.

[5] Note that these represent grab samples but, with the exception of TP and phosphate, the numbers are within the annual range measured at the LWRF facility. Annual effluent averages for TP and phosphate are 520 µg/l and 280 µg/l, respectively.

Lahaina Deep Monitoring Wells	327-452	26.1-27.4	73.1-91.1	52-55	2342-2759	1210-1608	43-58
Ukumehame[6]	437	22	na	na	na	9100	44
Kaanapali 4	258-265	18-21	81-85	59-63	1780-1878	1671-1707	34-35
Kaanapali 5	132-201	12-14	60-72	48-54	1461-1562	1146-1152	18-25
Kaanapali 6	91-277	7-21	69-93	68-77	2429-2500	1916-2487	13-36
Hahakea 2	143-185	13-18	252	191	2094	1420	
SELECTED OCEAN SAMPLES							
Submarine Springs	1469-8585	69-164	350-468	279-415	651-1624	96-366	201-1191
Maui 14	35745	2033	13	3.1- 6	75.9-187.2	7.6-17.8	4150
Maui 12	32466	1936	12.1-12.7	3.4-5	100-178	0.8-32	4342
Black Rock 1	1732	93	261	155	4755	3447	248
Black Rock 2	13275	853	123	61.3	2146	1083	1800

The data in **Table 1** are remarkable for several reasons. First, the TN and nitrate concentrations measured in the SS, as reported, are roughly a factor of 10 less than in the LWRF effluent injected into the aquifer. Clearly, either the spring water at the time of sampling comprised water that is different from the effluent, or a substantial fraction (90%) of the nitrate was consumed in the aquifer and therefore not discharged from the springs. However, based on data obtained from HDOH surveys of the spring water, the nitrate levels in the grab samples described in the June and September surveys in the *Interim Report,* and excerpted in **Table 1**, are not typical (96-366 µg/l) and are lower than average. The data from HDOH monthly samplings (**Table 2**) show much higher average concentrations of nitrate plus nitrite in the spring water (304-1109 µg/l), and it is difficult to reconcile the low concentrations of nitrate in the *Report* with these much higher concentrations in the HDOH samplings.

Table 2 – HDOH average coastal monitoring data from 1/25/2012-7/14/2014

Sample Location	**Average NH_3-N (mg N/L)**	**Average NO_3^- + NO_2^-- N (µg/L)**	**Average Total N (µg/L)**	**Average Total P (µg/L)**
North seep A	7	827	1504	385
North seep B	3	1109	2078	458
North seep C	3	304	0404	367
South seep A	4	753	1542	452
South seep B	4	664	1222	452
South seep C	4	717	1367	416
OTHER COASTAL				
Wakihuli	9	59	126	31
Black Rock	6	3043	3800	235
Ukumehame	4	1	38	12

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[6] Cox and Thomas (1979)

The second remarkable fact is that the TP concentration of the SS water is roughly between 2 and 3 times the concentration of TP in the effluent, as reported. The source of this phosphorus is not evident although higher phosphorus levels are also evident in Black Rock Lagoon and within the groundwater at Hahakea. However, as noted in the footnote to **Table 1** the average TP in LWRF plant effluent reported is 520 µg/l and the average phosphate is 280 µg/l, numbers that are closer to, but higher than, the range measured in the springs in the June and September samplings. As shown in **Table 2** the average concentration of TP in the HDOH spring samplings is much higher than shown in the June and September grab samples in the *Report*.

The concentration of magnesium in the SS water is between 2 and 5 times that in the LWRF effluent. In addition, the measured chloride and sulfate concentrations of the SS water are roughly between 3 and 15 times that of the LWRF effluent. It is therefore evident that the SS springs are not simply undiluted LWRF effluent and must contain water from other sources. Since the aquifer material (basalt) is known to contain very little chloride (Iwasaki and Katsura, 1964) the SS water must contain a significant fraction of sea water as there is apparently no other source for the chloride; water in upland wells and effluent is low in chloride. Sea water also contains a high concentration of magnesium and sulfate so the elevated levels of magnesium and sulfate in the SS water confirm that the higher salinity of SS water is a result of mixing with some seawater. However, seawater is low is phosphorus content so there must be some other phosphorus source to provide the elevated phosphorus concentration in the SS water.

In the samples taken in June and September the injected effluent had a TP concentration of 164-206 µg/l, of which approximately 50% is phosphate (PO_4^{3-}). By contrast the seeps have TP content of 350-468 µg/l, of which about 80-90% is phosphate. Clearly phosphate is being supplied within the aquifer. It is known that basic lava aquifers (Hawaiite) contain olivine and other phosphorus containing minerals with phosphorus content in the range 0.3-1.3%. Research has also shown that phosphate solubilizing microorganisms (PSM)[7] do exist that can release phosphates from otherwise insoluble states; whether PSM exist in Hawaii is unknown. However, it is known that Hawaiite-type basaltic lavas do lead to elevated phosphorus levels in groundwater that can provide phosphate concentrations high enough to sustain algae blooms in reservoirs (Lynn, 2005).

An examination of other sample data shows that the source of Black Rock lagoon water, which is not directly influenced by the LWRF effluent, must also have available phosphorus. The upland well water, represented by Hahakea 2, does have an elevated phosphate content (191µg/l) that exceeds the Black Rock surface water samples by Glenn *et al*., but not that in samples by HDOH (see **Table 2**). This provides another clue as to the possible source of phosphorus in the springs as the Hahakea 2 well, which is located in the high ground east of the LWRF, and is within the historical sites of pineapple and sugar cane plantations[8]. The phosphate concentration in the Hahakea well is about the same as in the LWRF effluent. (Note also that the nitrate concentrations in the Ukumehame and Kaanapali wells P-5 and P-6, also in the upland plantation land, approach the concentration in the treated effluent and greatly exceed that in the SS samples in **Table 1**.) This groundwater must make its way to the sea driven by the available hydraulic gradient and it is possible that it is responsible for the high phosphate concentrations in the submarine springs, since upland well water cannot be ruled out as a dilutant of the effluent injected into the aquifer.

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[7] http://en.wikipedia.org/wiki/Phosphate_solubilizing_bacteria

[8] http://pubs.usgs.gov/sir/2012/5010/sir2012-5010.pdf .

Now, addressing the claim that the water near (emphasis added) the seeps has "exceptionally elevated" levels of nitrogen and phosphorus, it can be seen from the data in **Table 1** that the TN and nitrate levels in the SS water are much less than the concentrations of TN and nitrate at Black Rock. The phosphorus levels in the SS water are of the same order as those at Black Rock. The claim of "exceptionally elevated" nitrogen and phosphorus concentrations near the seeps has no basis in the data presented in the *Report*. (See also discussion of dilution in Section 3.3(e) below). **Table 3** below presents the nitrogen and oxygen isotopic anomaly data for the samples listed in **Table 1**. It is apparent that there is a significant increase in the nitrogen 15 and oxygen 18 anomalies for the effluent and the submarine springs, relative to waters other than Maui 14 and 12, which are the two sampling stations closest to the southern seeps (see inset to **Exhibit 16**). The increase in δ^{15}N is ascribed to isotopic fractionation by denitrifying micro-organisms within the aquifer. The claim that the "highest levels of sewage-derived nitrogen ever reported in the scientific literature" is based upon these elevated δ^{15}N numbers in macroalgae placed in the nearshore.

There are three primary errors in this statement. First, the declaration does not state "highest levels of sewage-derived nitrogen". It states: "…that algae samples grown over freshwater seeps in Kahekili's nearshore waters contained the highest δ^{15}N values ever reported in the scientific literature." Second, δ^{15}N values do not measure *levels* of nitrogen, sewage-derived or otherwise. They measure the *fraction* of the isotope N15 to isotope N14, relative to that ratio in air. The ratio is increased by isotopic fractionation processes that preferentially remove N14 nitrate thus increasing the fraction of N15 in the nitrate sample. Biological processes in animals and in the earth can increase this ratio. The ratio of N15/N14 in the LWRF effluent is approximately 0.00379 (δ^{15}N ≈30). The ratio within the springs is approximately 0.00401 (δ^{15}N≈90). At Kahekili Beach δ^{15}N does not uniquely identify sewage-derived nitrogen since, as noted previously, there are multiple sources of nitrogen within the groundwater moving towards the coastline. The high δ^{15}N numbers would only uniquely define sewage-derived nitrogen if there were no other sources of nitrate nitrogen.

As noted above, the upland well waters, which must move toward the coast and which contain high levels of agriculturally-derived nitrogen, cannot be excluded as a dilutant of the effluent within the aquifer, and if they do so they would also be subjected to isotopic fractionation, as has been observed elsewhere in the world (Böttcher, 1990). This nitrate, derived from agricultural practices, would be subjected to isotopic fractionation in the same way that apparently occurs with effluent-derived nitrate, so that a fraction of the N15 measured in the submarine spring nitrate and the macroalgae could well have its origin in upland groundwaters. The claim that the highest levels of "sewage-derived" nitrogen are present in the near shore waters is based on the assumption that the nitrate in the submarine springs derives solely from the wastewater effluent, which is clearly unlikely. The fact that some of the δ^{15}N anomaly may result from entrainment and denitrification of upland ground water cannot be excluded. The claim that the high levels of nitrogen are uniquely "sewage-derived" is therefore unscientific and speculative because the denitrification of groundwaters derived from upland infiltration cannot be ruled out. As shown in **Table 3,** Black Rock Lagoon water also has elevated δ^{15}N (see also **Exhibit 18** discussed below).

Table 3 – Isotopic anomaly measurement data.

Source	δ^{15} N (NO3)	δ^{18}O (NO3)
LWRF Effluent	29-31	16-20
Submarine Springs	87-93	23-25
Lahaina Deep Monitor Well	2	-0.2-0.8
Kaanapali 4	0.9-2.0	-0.27-4.30
Kaanapali 5	2.4-4.2	0.5-3.0
Kaanapali 6	3.3-3.5	0.33-3.3
Maui 14	55	15.5
Maui 12	58	21.6
Black Rock 1	8.8	2.3
Black Rock 2	8.8	2.4

To put the issue of nitrogen nutrient sources into perspective **Table 4** has been excerpted from Table 3-6d of the *Interim Final* Report and it provides the estimated fluxes of DIN nutrients to the coastline. Note that the Black Rock Lagoon estimate is based on an estimated groundwater flow and does not include the tidal pumping flux of water and nutrients from the Lagoon. It is therefore likely that the flux of nutrients from the Lagoon in **Table 4** is grossly underestimated as it is based on the estimated freshwater flow from the lagoon and not the tidal flushing (see Fischer *et al*., 1979, p. 266, for a discussion of tidal flushing).

Table 4-Estimated flux of dissolved inorganic nitrogen to the ocean

Site	Est. GW Discharge (mgd)	DIN Flux (g/d N)
Black Rock	0.59	7381
SSG	1.66	1,126-2,524
NSG	0.66	282-528
S. Honokowai	1.88	13,070
N. Honokowai	2.09	14,543
Hanakao'o Beach	7.40	41,437
SSG+NSG %	16.00	1.8-3.8

It can be seen that according to these data, although the SS water provides an estimated 16 percent of the near shore groundwater inflow it only provides between 2 and 4 percent of the DIN to the coastline between Hanakao'o Beach and N. Honokowai. This indicates that the SS can hardly be recognized as a significant source of DIN.

Although the data analysis above discusses only the effluent from Wells 3 and 4 similar conclusions are valid for the discharges from Wells 1 and 2 since effluent from these wells will be even more diffuse and diluted.

The effluent injected into the aquifer using Wells 1, 2, 3, and 4 therefore must comingle within the aquifer with other sources of nitrate and phosphate. The effluent mixed with other sources therefore cannot form a discrete and discernible discharge to the ocean.

3.3 The Reports' and Plaintiffs' analysis and conclusions regarding certain Tracer Study parameters are inaccurate

3.3(a) Acidic waters

The acidity of water is measured by a number referred to as pH. The number is derived from the negative logarithm of the hydrogen ion activity, which is a measure of the effective concentration of hydrogen ions. Pure water has a pH of close to 7.0 and is considered neutral and acidic water has a pH less than 7. If the pH is higher than 7 the water solution is referred to as basic. Natural seawater has a pH of about 8 and is therefore basic. Rainwater **in** Hawaii typically has a pH of 5.6-5.8 and creeks about 7.9[9]. The submarine spring seeps have a pH of about 7.5 (*Report*, Table 2-2), but range from 7.0 to 7.9, in other words are not acidic. It is misleading to describe water with a pH of 7.5 as being more acidic than a water of pH 8 when both are basic; a pH of 7.5 is properly described as less basic than a pH of 8.0.

The range of pH of water in the NSG and SSG is presented in Table ES-1 of the *Interim Report* and the data on which this summary is based are presented in Tables A-3 and A-4 of the *Report*. A statistical analysis of these data shows that the mean pH of water ***within*** the seeps has an average of between 7.35 and 7.69 (*Report*, Table ES-1). The measured pH at the ***nearshore*** Maui ocean sampling points M-1 through M-34 (including the sample points nearest the springs) was between 8.07 and 8.14 (*Interim Report*, Tables 6-5 and 6-6). By contrast, the three control Stations (Honokowai Beach Park, Wahikuli Wayside Beach Park and Olowalu, see Table A-5 of *Report*) had an average pH of 8.05 with a standard deviation of 0.08. As will become apparent in the discussion of spring dilution in Section 3.3(e) these results are not unexpected.

In summary, the waters **near** the submarine seeps have a pH that is statistically indistinguishable from the control stations and there is no foundation on which to claim that water **near** the seeps is substantially more acidic than the rest of the ocean's nearshore water.

Since the effluent from Wells 1 and 2 is even more diffuse and diluted it is to be expected that any impact on nearshore pH from these wells will also be undetectable.

3.3(b) Salinity of seeps

Groundwater is naturally lower in salinity than seawater. The salinity of water discharged at the seeps cannot be attributed to the effluent, which is less than 3% of the salinity of seawater. All rainwater that falls on an island and infiltrates either flows off the land as surface streams, or emerges at the shoreline as groundwater SS and diffuse flow. Despite the claim in the *Report* of the recent discovery of the springs at Kahekili Beach the existence of submarine freshwater springs at Lahaina has been known

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[9] https://www.soest.hawaii.edu/GG/ASK/rain-creek-pH.html

for a very long time. Their presence existence is mentioned in an article by Dartmouth Professor Charles Hitchcock in the December 1905 edition of *Popular Science Monthly* Volume 67, page 680:

> "Inquiry about these springs during the past summer in the territory of Hawaii has resulted in the discovery of several upon Oahu, there is one off Diamond Head; a second off Waialae. At the east end of Maui, in Hana, there was a fortress named Kaimuke, occupied by soldiers in the ancient times. As it was almost an island communication with the mainland was not feasible in the time of a siege, and for the lack of water it could not have been held except for the presence of submarine springs. The natives would dive down to collect water in their calabashes, which supplied all the wants of the garrison. Other springs were known in the harbor of Hana, and at low tide at Lahaina. Upon Hawaii I found there were fresh-water springs off Kawadahae and Punaluu. Further inquiry would doubtless discover many other examples."

In summary, freshwater seeps within the coastal waters of islands are a natural condition that can only be controlled by intercepting the groundwater flow with production wells located inshore of the seeps. The seeps will persist as long as rain continues to fall on the island. The presence of identifiable warm springs containing salt water and high concentrations of radon and radium at Kahekili Beach will be shown below to be a result of geothermal activity.

3.3(c) Dissolved oxygen

DO concentrations are discussed in Table 6-17 of the *Interim Report* and data are presented from a study referenced as Swarzenski *et al.* USGS Open File Report 2012 (Swarzenski *et al.*, 2012). However, this USGS report does not contain any such dissolved oxygen (DO) data, and in fact, states that although such data were measured they are not included in the report. However, there are HDOH data available from samples taken approximately monthly between 01/25/2012 and 07/14/2014. These data include seep samples and samples taken at control stations north and south of the seeps. A typical data sheet is shown in **Table 5**.

An analysis of all DO data collected by HDOH over the period 1/25/2012 -7/14/2014 is presented in the following **Table 6**. For comparison, the DO concentration in the injected effluent is of the order of 6.9±0.3 mg/l.

A review of the data in **Table 6** indicates that although the average DO concentration ***within*** the springs is 5±1, the DO in the water column immediately above the springs is within the range for the control sites. In other words, the rapid mixing of the spring water with ambient ocean water above the spring increases the DO concentration to ambient levels. By comparison, the DO levels at Black Rock Lagoon are much lower. The average DO levels within the springs measured by HDOH are far from anoxic levels and as such are inconsistent with the suggestion in the *Report* that the lower nitrate and nitrite concentrations measured in the springs in the June and September surveys are a result of denitrifying micro-organisms, since it is believed that the action of denitrifying organisms is inhibited by the presence of DO.

In summary, the HDOH DO data make clear that although the DO of water ***within*** the springs is lower than the effluent DO (likely because of oxidation processes in the aquifer) and also lower than marine water elsewhere in West Maui, the DO in the water column immediately above the springs has DO concentrations that are within the range of DO concentrations of marine waters elsewhere in West Maui.

In that the seepage from Wells 1 and 2 is more dispersed than that associated with Wells 3 and 4 there will be no detectable effect on DO by effluent from Wells 1 and 2 on nearshore ocean waters.

Table 5 – Dissolved oxygen concentrations in submarine springs 02/24/2014 (typical).

Sample No.	Location	Location Name	Time	Temp C	Sal PPT	DO mg/l	DO%	pH
RA02241401	special	control north surface	915	24.59	35.21	6.02	89.6	8.34
RA02241402	special	control north mid-depth	920	24.57	35.21	6.06	90	8.32
RA02241403	special	north seep surface	926	24.63	34.55	5.97	88.8	8.31
RA02241404	special	north seep mid-depth	929	24.62	34.69	5.85	86.8	8.27
RA02241405	special	north seep A	920	25.44	4.56	4.53	57.3	7.99
RA02241406	special	north seep B	944	26.74	6.3	4.55	80.6	8.03
RA02241407	special	north seep C						
RA02241408	special	south seep A	1044	27.03	3.55	5.24	68.1	7.78
RA02241409	special	south seep B	1101	27.62	3.66	5.38	71.1	7.78
RA02241410	special	south seep C	1126	28.02	7.68	5.66	75.6	7.95
RA02241411	special	south seep surface	1052	25.22	34.73	6.73	100.9	8.31
RA02241412	special	south seep mid-depth	1055	25.22	34.73	6.69	100.3	8.32
RA02241413	special	control south surface	1101	25.26	34.8	6.71	100.8	8.36
RA02241414	special	control south mid-depth	1105	25.26	35.02	6.78	101.9	8.33
RA02241415	special	Wahikuli	745	24.08	32.31	6.31	91.1	8.26

Table 6 – Average and standard deviation of DO data collected by HDOH.

Site	Average DO (mg/l)	Standard Deviation
North Control[10]	6.07	0.35
South Control[11]	6.87	0.35
Within Seep[12]	5.09	0.97
Seep Water Column[8]	6.39	0.34
Black Rock[13]	4.40	0.42

3.3(d) Water temperature

First, let us examine some of the temperature data measured in the SS and reported in the *Interim Report* Tables A-3 and A-4. These data show rapid and substantial changes occur in measured spring water temperature. Some examples from these tables are presented in **Table 7**.

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[10] Average of 27 months
[11] Average of 26 months
[12] Average of 31 months
[13] Average of 7 months

Table 7 – Sample seep water temperatures.

Seep 3

Date	Time	Temperature (°C)	pH
9/10/2011	11:36 am	30.4	7.41
9/12/2011	12:39 pm	32.3	7.44
9/13/2011	11:52 am	33.3	7.55
9/14/2011	10:49 am	32.1	7.53
9/15/2011	10:27 am	33.2	7.77
9/16/2011	12:20 pm	34.9	7.63
9/17/2011	3:37 pm	31.5	7.41
11/1/2011	12:26 pm	33.3	7.61
11/3/2011	10:21 am	29.9	7.57
11/5/2011	2:29 pm	33.4	7.56

Seep 4

Date	Time	Temperature	pH
9/12/2011	12:55 pm	29.2	7.48
9/13/2011	12:07 pm	32.9	7.55
9/14/2011	11:03 am	31.9	7.51
9/15/2011	10:45 am	33.5	7.85
9/16/2011	12:31 pm	34.6	7.55
9/17/2011	3:50 pm	31.5	7.49

Similar fluctuations to those shown highlighted above occurred in other seeps, as noted in Table 2-2 of the *Report*, where temperature variations from 23.8 °C (7/29/2011) to 35.9°C (9/18/2011) [73.8°F - 96.6°F] were recorded in Seep 6. In some cases temperatures changed by as much as 5°C (9°F) within a day (Seep 6 on 8/6/2011 between 9:20 am and 3:30 pm.)

These rapidly fluctuating and elevated temperatures have been ascribed in the *Report* to three possible sources: geothermal heating, elevated temperature injected effluent and exothermic heating from biological activity within the aquifer. The latter two are simply inconsistent with the rate at which temperature fluctuations occurred and in any case can be rejected on other grounds.

First, the maximum recorded temperature of injected effluent temperature is 30.9 °C and the effluent temperature is generally in the range 25.5-28.6°C and averages 27.5 °C and thus clearly could not give rise to a spring water temperature as high as 35.9°C, which was recorded at the submarine springs. Furthermore, in the months the effluent is within the aquifer any temperature fluctuations in the injected effluent would be filtered out by the thermal inertia of the aquifer. (Thermal inertia is a result of the fact that it requires significant heat to change the temperature of an aquifer containing water so the effect on water traveling a significant distance through an aquifer is to smooth out any temperature fluctuations in the incoming water.)

Second, the concentration of biological and other compounds, such as nitrates, in the effluent is such that the heat generated by biological activity could only result in a fraction of a degree rise in injected effluent temperature. Studies (Gallert and Winter, 2005) have shown that the heat generated by biological oxidation is of the order of 900 kiloJoules/Mole (kJ/M) of organic material. If we estimated (from the BOD, suspended solids and Kjeldahl nitrogen, etc) that the effluent contained 10 mg/L of oxidizable material with a molecular weight of 180 (glucose equivalent) then the heat released would cause the effluent temperature to rise by about 0.01 °C. If, in addition, denitrifying bacteria reduced all available nitrate (roughly 7 mg/l) with a molecular weight of 62, this would produce another 880 kJ/M (Samuelsonn *et al.*, 1988), and the added temperature increment would be about another 0.02°C. In other words, any exothermic biological action within the aquifer would have a negligible effect on the temperature of the injected effluent.

Given the high temperatures recorded in the springs we have to conclude that the source of heat generating the temperature fluctuations in the seeps is actually geothermal energy. It is well known (McKibbin and O'Sullivan, 1980) that groundwaters heated from below by geothermal activity are convectively unstable and give rise to intermittent "bubbles" of warm water that rise through an aquifer. The fluctuations and elevation in seep water temperature can be explained by this mechanism. The rising bubbles of heated liquid also cause entrainment of ambient fluid, in this case likely salt water, into the plume so generated.

There is also additional evidence that the temperature fluctuations have a geothermal origin. Kitamura (1980) noticed the geothermal potential in the Lahaina area. "Based on ground radon emanations, soil mercury measurements and chloride/magnesium ion anomaly, it appears that the Ukumehame region, located on the south rift of the West Maui Mountains shows the "best" geothermal potential. Other areas which also look good are the Lahaina/Kaanapali and the Haiku/Paia regions".

Records of geothermal activities in Lahaina and in the larger West Maui area date back at least to the 1930s. "The West Maui Volcano has not been active in historic times. Thus, the discovery of thermal waters in the 1930s, a product of volcanic activity, was not anticipated in West Maui wells. However, distinctly warm waters were found on the leeward side of West Maui in three groundwater developments: drilled wells at the Pioneer Mill in Lahaina (30 °C); (2) a Maui-type well in Ukumehame (35 °C); and (3) a high-level horizontal water development tunnel in Olowalu (24 °C)" (Kennedy, 1985). The *Interim Report* (p. 101) also pointed out that "the most recent volcanism on West Maui occurred near Lahaina".

As noted in Table 4-3 and Figure 4-6 of the *Interim Report* the chloride:magnesium ratio in the submarine seeps is consistent with a geothermal source influencing the seep water. In addition, Thomas (1986), identified the rift zone of West Maui near Honokowai as a potential geothermal resource area, but was unable to detect any groundwater temperature anomalies, such as had been found at Ukumehame. It appears that now, based upon the high temperatures observed in the SS water, that the conjecture was correct and that the Honokowai rift zone has geothermal activity.

Groundwater temperature is one of the most often-used properties to quantitatively assess geothermal flows. Very limited groundwater temperature data were provided in the *Interim Report* and the *Report*. The temperature of groundwater in upland wells (see **Exhibit 16** for locations) was presented in Tables 6-5 and 6-6 of the *Interim Report* (pp. 178-181) for June and September 2011. Groundwater temperatures measured at the Starwood Vacation Resorts (SVO) wells on 7/31/2012, 4/29/2013 and 6/6/2013 were presented in Table 4-23 and Appendix D of the *Report*. Groundwater temperature in

SVO Well 5 was 28.64 °C on 7/31/2012 (Table D-1 of the *Report*), and temperature in Well 5 was not measured on 4/29/2013 and 6/6/2013.

Sampling at the NSG and SSG ceased in December 2012. Therefore, temperatures of the SSG and NSG discharges can only be compared with SVO well temperatures measured on 7/31/2012. These very limited data, presented in **Table 8**, showed that groundwater temperatures measured in SVO Wells 4 and 5 were significantly lower than the temperature of the spring discharges in NSG and SSG, although these two SVO wells are within 0.25 mile of the NSG and SSG (see *Report*, Figure 4-26 for SVO well locations.) This temperature difference indicates there must be a heat source in this area raising the temperature of the spring discharges. The SVO Wells 4 and 5 are within the modeled plume of the LWRF effluent, and therefore, the groundwater temperatures in these two wells should already reflect the heating effect of any warm effluent. The large temperature differences between the SVO wells and the spring discharges also rule out heating by biological processes. Thus, geothermal activity is the only possible heat source.

Table 8 – Temperature Data for 7/31 – 8/1/2012

Location	Date	Time	Temperature (°C)	Salinity
SVO Well 4	7/31/2012	16:50	27.04	1.5[a]
SVO Well 5	7/31/2012	12:28	28.64	0.5[a]
NSG[b] Seep 18	8/1/2012	9:20	31	4.7
SSG Seep 3	8/1/2012	10:35	31.7	3.2
SSG Seep 5	8/1/2012	11:05	29.7	3.6
SSG Seep 11	8/1/2012	11:31	30.4	4.4

[a] Salinity value estimated from SEC presented in Table D-1 of the *Report*.
[b] NSG and SSG data were from Tables A-3 and A-4 of the *Report*.

Since there is sufficient geothermal flow to raise the effluent temperature from 26-28°C to as high as 35.9°C this means that at times a fraction of the water in the seeps is likely to be seawater and high nitrate upland water mixed into the effluent plume by the creation of a vertical plume of warm water "bubbles" created by geothermal heating, as described in McKibbin and O'Sullivan (1980).

To estimate the fraction of geothermally driven flow in the SS discharges, the SS discharges are therefore assumed to be a mixture of seawater, upland groundwater flow and LWFR effluent. The fraction of water from the three sources in the SS discharges for any data set can be estimated from the salinity and temperature data of the source waters. The equations for calculating the source water fractions are listed below.

$$
\begin{aligned}
&f_s + f_g + f_t = 1 \\
&S_s f_s + S_g f_g + S_t f_t = S_m \\
&T_s f_s + T_g f_g + T_t f_t = T_m
\end{aligned}
$$

Where subscripts s, g, t, and m stand for geothermally mixed seawater, upland groundwater, LWRF effluent flow, and measured SS discharge, respectively; f is the flow fraction, S is salinity and T is temperature. The input values for this calculation are dependent upon the time at which the data were acquired because it is clear that the salinity and temperature of the springs fluctuate. Thus application of this analysis is appropriate for a given data set to indicate the relative fractions of flow at that time. It is recognized that the temperature of the upland water and LWRF near the spring site will be essentially equal because of the thermal inertia of the aquifer. The following data set is used in the analysis.

S_s = 35, which is the seawater salinity used in the *Report* (p. 4-20).
S_g = 1, which is the average of salinity values in SVO Wells 4 and 5, as shown in **Table 8**.
S_t = 1.1 as shown in Tables 6-5 and 6-6 (*Interim Report*).
S_m = 4.7 for NSG, and S_m = 3.7 for SSG, which is the average salinity measured at the three SSG springs, as shown in **Table 8**.
T_m = 31 °C for NSG, and T_m = 30.6 °C for SSG, which is the average temperature measured at the three SSG springs, as shown in **Table 8**.
T_g = 27.8 °C, which is the average of temperature values in SVO Wells 4 and 5, as shown in **Table 8**.
T_t = 27.8°C, which is assumed the effluent temperature based on SVO well temperatures.

No temperature data are available for the geothermally heated seawater flow and, as a result, the fraction of geothermal flow in the SS discharges cannot be estimated directly. Instead, a possible temperature range was assumed for the geothermal flow, and the fraction of LWRF flow in the SS discharges was estimated based on a range of temperatures of the geothermal flow. The geothermal flow temperature is likely higher than 36 °C, since the highest temperature recorded at the NSG and SSG is 35.9°C (Table A-4 of the *Report*, p. A-40).

The results of mixing calculations show that for this specific set of data the geothermally-driven water fraction is basically defined by the salinity constraint to be about 11%. And since the temperature of the upland groundwater and the LWRF waters are likely to be the same because of the thermal inertia of the aquifer, the temperature of the SS water is controlled by the temperature of the geothermally heated water. The calculations indicate that for a SS temperature of about 31°C the fraction of upland water is about 50% and the fraction of LWRF water about 40% and the temperature of the geothermally heated water needs to be about 50°C to give realistic fractions of LWRF and upland groundwater. It is noted that the computed fractions of upland freshwater and the LWRF water are sensitive to the imputed temperature of the geothermal waters input into the computation.

In summary, for the example given the mixing fractions based on salinities and temperatures all give reasonable numbers, but are probably not very accurate. Nevertheless, the basic conclusion is that the salinity and temperature of the springs are consistent with a geothermal source of seawater with a temperature of about 50°C adding something like 11% to the spring flow during a high temperature excursion. On this basis the LWRF effluent represents about 40 percent of the heated spring flow, which as noted previously (see **Exhibit 14**) represents at maximum less than 4% of the effluent flow.

The conclusion that the springs are significantly impacted by geothermal activity has a number of implications with respect to this case. The obvious one is, of course, temperature. It is clear from the above that the wastewater effluent cannot be held responsible for any thermal anomalies measured in the near shore coastal waters off of Kahekili Beach. In the absence of any other rational explanation for the water temperature increase it has to be concluded that this is of natural origin.

The geothermally-driven mixing of seawater and other waters explains the elevated concentrations of magnesium, chloride and sulfate in the spring waters and the fact that both the concentrations of these constituents and the temperature fluctuate. It is also likely that the gas emitted from the springs has a geothermal component. Hydrothermal springs very commonly have bubbles rich in nitrogen, argon and carbon dioxide, all gasses that were measured in the springs (*Interim Report*, Table 6-11 p. 192). Furthermore, despite the high fraction of nitrogen gas in the bubbles (98% vs 80% in normal air) there is no elevation of the δ^{15}N levels in the gas (data received from U of H, 2014). If the added nitrogen were from denitrification of effluent nitrate, then based on the reduced concentration of nitrate nitrogen in the seeps relative to the LWRF effluent and the elevated δ^{15}N values within the seeps, we should expect that the gas would have a δ^{15}N of approximately 6, not zero. This indicates that the nitrogen gas in the seeps is more likely from a geothermal source and not denitrification.

Finally, one further piece of information also very strongly suggests that the springs are of geothermal origin. Tables 5-1 and 5-6 of the *Interim Report* (reproduced below) describe the radon 222, radium 224 and radium 223 concentrations in the spring and well water. Radon 222 and radium 224 have half lives of 3.8 and 3.7 days respectively and radium 223 has a half life of 11.4 days. These isotopes must therefore have a very local source as radioactive decay would have otherwise reduced the concentrations. It can be seen that the concentration of these three radioactive isotopes is very much higher in the spring water than in the upland well waters. High concentrations of radioactive isotopes of radon and radium commonly occur in thermal springs (Momoshima, 2000; Field, 2008).

Table 9.1 Radon concentrations in groundwater

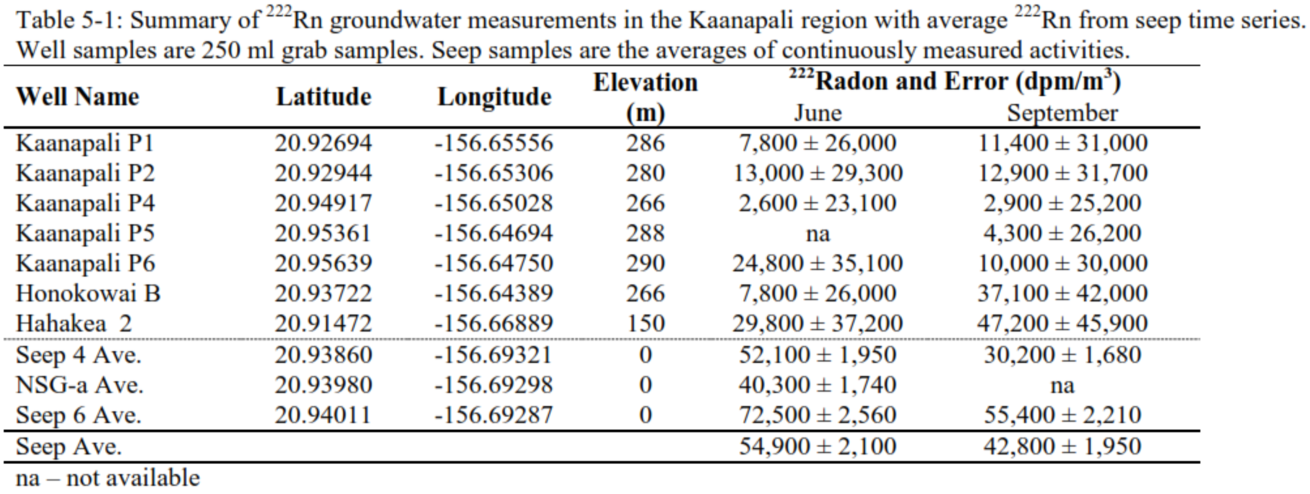

Table 5-1: Summary of ^{222}Rn groundwater measurements in the Kaanapali region with average ^{222}Rn from seep time series. Well samples are 250 ml grab samples. Seep samples are the averages of continuously measured activities.

Well Name	**Latitude**	**Longitude**	**Elevation (m)**	**^{222}Radon and Error (dpm/m^3)** June	September
Kaanapali P1	20.92694	-156.65556	286	7,800 ± 26,000	11,400 ± 31,000
Kaanapali P2	20.92944	-156.65306	280	13,000 ± 29,300	12,900 ± 31,700
Kaanapali P4	20.94917	-156.65028	266	2,600 ± 23,100	2,900 ± 25,200
Kaanapali P5	20.95361	-156.64694	288	na	4,300 ± 26,200
Kaanapali P6	20.95639	-156.64750	290	24,800 ± 35,100	10,000 ± 30,000
Honokowai B	20.93722	-156.64389	266	7,800 ± 26,000	37,100 ± 42,000
Hahakea 2	20.91472	-156.66889	150	29,800 ± 37,200	47,200 ± 45,900
Seep 4 Ave.	20.93860	-156.69321	0	52,100 ± 1,950	30,200 ± 1,680
NSG-a Ave.	20.93980	-156.69298	0	40,300 ± 1,740	na
Seep 6 Ave.	20.94011	-156.69287	0	72,500 ± 2,560	55,400 ± 2,210
Seep Ave.				54,900 ± 2,100	42,800 ± 1,950

na – not available

Table 9.2 –Radium isotopes in groundwater

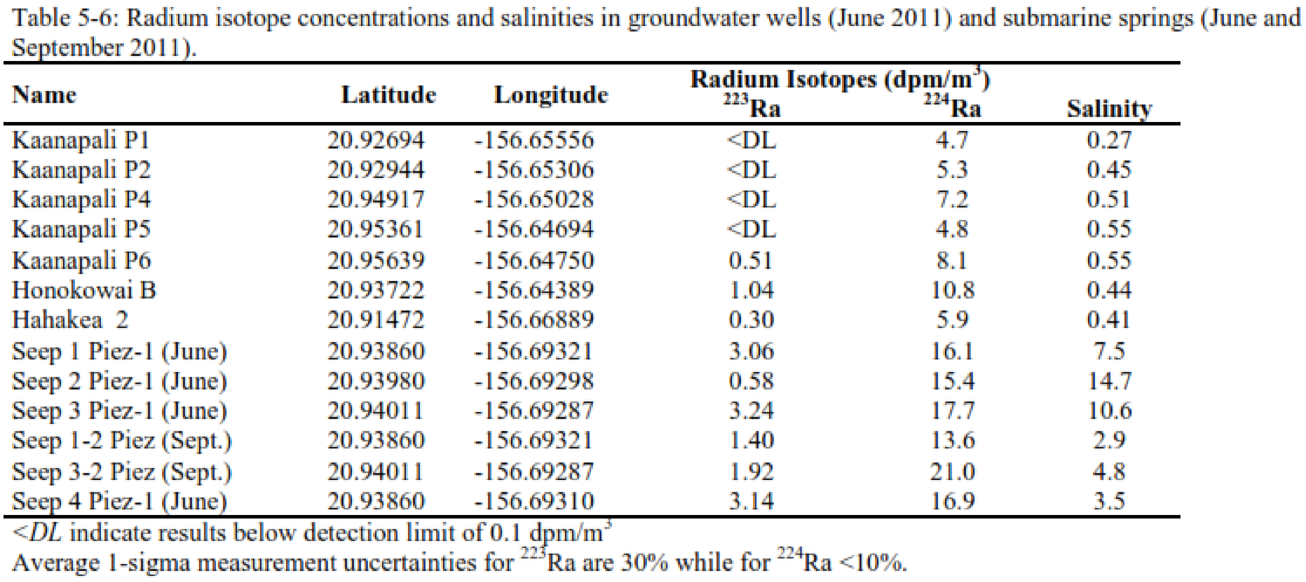

Table 5-6: Radium isotope concentrations and salinities in groundwater wells (June 2011) and submarine springs (June and September 2011).

Name	Latitude	Longitude	Radium Isotopes (dpm/m^3)		Salinity
			^{223}Ra	^{224}Ra	
Kaanapali P1	20.92694	-156.65556	<DL	4.7	0.27
Kaanapali P2	20.92944	-156.65306	<DL	5.3	0.45
Kaanapali P4	20.94917	-156.65028	<DL	7.2	0.51
Kaanapali P5	20.95361	-156.64694	<DL	4.8	0.55
Kaanapali P6	20.95639	-156.64750	0.51	8.1	0.55
Honokowai B	20.93722	-156.64389	1.04	10.8	0.44
Hahakea 2	20.91472	-156.66889	0.30	5.9	0.41
Seep 1 Piez-1 (June)	20.93860	-156.69321	3.06	16.1	7.5
Seep 2 Piez-1 (June)	20.93980	-156.69298	0.58	15.4	14.7
Seep 3 Piez-1 (June)	20.94011	-156.69287	3.24	17.7	10.6
Seep 1-2 Piez (Sept.)	20.93860	-156.69321	1.40	13.6	2.9
Seep 3-2 Piez (Sept.)	20.94011	-156.69287	1.92	21.0	4.8
Seep 4 Piez-1 (June)	20.93860	-156.69310	3.14	16.9	3.5

<*DL* indicate results below detection limit of 0.1 dpm/m^3

Average 1-sigma measurement uncertainties for ^{223}Ra are 30% while for ^{224}Ra <10%.

In summary, the elevated and fluctuating temperature of the spring water, the chloride-magnesium ratio, the free nitrogen gas bubbles with zero δ^{15} N and the high levels of radioactive isotopes in the spring water, are all congruent with the springs being geothermally driven by a local heat source. The springs are not relevant to the discharge from Wells 1 and 2 because the plume from these wells is dispersed and diffused elsewhere.

3.3(e) Dilution of effluent

The near shore water quality sampling data collected by the University of Hawaii researchers and the HDOH make it very clear that the effluent discharged into the aquifer and ultimately released to the ocean is rapidly dispersed into the coastal waters. Tables 6-8 and 6-10 from the *Interim Report* give sample data from June and September, respectively, for the ocean spring seeps and at 21 coastal locations near the seeps. HDOH monthly data are available for the period 1/25/2012 through 7/14/2014. The HDOH data are for nutrients, pH, DO and salinity within the springs (north and south), at mid-depth and surface immediately above the springs and at control locations north and south of the spring seeps. These data enable a dilution analysis to be performed, the results of which disclose how rapidly the discharge from the springs is mixed with ambient water.

Let S_s be the concentration at the spring, S_t be the concentration at the ocean surface above the spring and S_e be the concentration in the ocean away from the spring. Then simple mass conservation implies that the dilution D is given by the formula

$$D = (S_s - S_t)/(S_t - S_e)$$

From Tables 6-8 and 6-10 we have data for silicon concentrations in the springs and at the surface and in the adjacent ocean. To be conservative we assume that the entrained ocean water that provides the diluting water has the minimum silicon concentration, i.e., if the S_e number is larger then the computed dilution is higher.

Table 10- Dilution of spring seeps computed from silicon concentrations.

June	S_s	S_t	S_e	D
Seep 1	20205	189	135	371
Seep 2	11984	229	135	125
Seep 3	15279	495	135	41
September				
Seep 1	21159	607	100	41
Seep 3	19693	298	100	98

According to the results of the computations the minimum immediate dilution of a spring discharge based on the silicon concentrations is at least 40 to 1. In addition to these silicon data the radon data also indicate very rapid mixing of the spring seep water with the ambient water. To quote from the *Interim Report* (pages 122/123):

> " Figure 5-3 shows that for all three submarine springs and during both June and September, ^{222}Rn measured directly from the submarine springs at the seafloor (~20,000-80,000 dpm/m^3) was enriched ten to forty times that which reaches the surface waters (~2,000 dpm/m^3). This suggests intense mixing of groundwater with seawater at a rate 10-40 times as the submarine springs mix into the coastal zone. Still, the ~2,000 dpm/m^3 measured in the surface waters is an order of magnitude above ambient ocean water radon levels (<100 dpm/m^3, Street at al., 2008), so despite the intense mixing, surface waters above the submarine springs were enriched tenfold the magnitude of background levels."

What the final sentence in the quoted paragraph fails to make clear is where the "background level" is located. The implication is that the springs were responsible for the ~2,000 dpm/m^3 in the surface waters, which would be the case if the measurements were above the springs. Appendix D of the *Interim Report* provides tables of time series of radon measurements in the surface waters above the springs. The concentration of radon seldom exceeded 2000 dpm/m^3 and, more to the point, to reach this low level from the high average concentrations in the seeps given in **Table 9.1** would require dilution with ambient water with a much lower concentration. As can be seen from the dilution formula above if the spring has 30,200 dpm/m^3 and the surface has 2000 dpm/m^3 the dilution would be 15.1, but only if the ambient diluting fluid had zero concentration of radon. If we use a more realistic but low ambient number of 500 dpm/m^3 for the fluid mixed into the rising plume the dilution becomes 19.8 rather than 15.1. Based on these numbers and the numbers for the seeps in **Table 9.1** the spring seep dilutions indicated by the average radon concentrations are more in the range 20-50 and are probably even higher. The 10-40 dilution numbers in the *Interim Report* assume dilution with water having zero radon concentration, which is simply not possible.

As Figure 5-5 of the *Interim Report* demonstrates, surface water concentrations of radon at a level of 2000 dpm/m^3 were also measured along the coast at N. and S. Honokowai to the north and at Hanakao'o Beach to the south. It is important to note that the higher radon levels is these areas were identified much earlier by Kitamura (1980), who ascribed them to geothermal activity.

The important point is that the intense mixing above the springs induces a dilution of the SS water by entraining ambient fluid. Applying the same logic as for the silicon and radon to the other water quality parameters in the SS explains why there is no statistical difference in DO, salinity and pH between the water immediately above the SS and the surrounding ambient water. The same dilution as occurs for silicon and radon will apply to every element and compound in the SS water, as is very apparent in the HDOH sampling data in **Table 11,** which presents the averages of nutrient concentrations within the SS, in the water immediately above the SS, and at control locations up and down coast from the location of the SS. Three other locations are also included for comparison.

Table 11- HDOH average monthly sample data 1/25/2012—7/14/2014

Location	Average TSS (mg/l)	Average NH_3-N (µg/l)	Average NO_3^- + NO_2^--N (µg/l)	Average Total N (µg/l)	Average Total P (µg/l)	Average Silica (µg/l)
North control mid-depth	11	3	5	57	18	548
North control surface	11	3	6	55	19	572
North seep A	6	7	827	1504	385	40600
North seep B	6	3	1109	2078	458	41200
North seep C	8	3	304	404	367	38400
North seep mid-depth	14	3	16	60	28	910
North seep surface	12	4	16	63	29	123
South control mid-depth	14	4	7	50	17	550
South control surface	14	5	7	68	20	610
South seep A	7	4	753	1542	452	42300
South seep B	10	4	664	1222	452	40600
South seep C	10	4	717	1367	416	38400
South seep mid-depth	14	4	17	88	23	770
South seep surface	14	4	16	64	25	880
OTHER LOCATIONS						
Wakihuli	13	9	59	126	31	2680
Black Rock	6	6	3043	3800	235	55700
Ukumehame	31	4	1	38	12	500

As is very apparent in the data in **Table 11** there is a huge difference in concentration of the measured nitrate + nitrite, TN, TP and silica between the samples within the SS and at the water surface above the SS. This is exactly what would be expected based on the radon and silicon dilution data. The remarkable fact is that the TN and TP levels immediately above the SS, although slightly higher than at the controls, are by comparison with the SS not that much different from the control locations. All of these data, radon, silicon, nitrates, TN and TP show that the immediate dilution of the SS is substantial, and of the order of at least 20-50. Furthermore, effluent in the diffuse seepage zone cannot be identified by any measured parameter such as pH, temperature, salinity, or nutrient concentration, and tracer dye concentrations in this zone were a factor of 10 less than in the SS, indicating a high rate of dilution and a diffuse entrance to the ocean. Any effluent discharged from Wells 1 and 2 will be similarly diluted.

3.3(f) Flow dynamics in the ocean

As discussed in Section 3.3(e), the site data show that the discharge from the SS is immediately diluted as it rises through the water column. The SS discharges rise because they are buoyant and the reason for this is primarily because they have a much lower salinity than the sea water environment. The buoyancy is also enhanced by the higher temperature of the SS waters and also by the presence of free nitrogen bubbles. As the radon data show, this dilution is of the order of 20-50, thus if the concentration of any constituent of the SS water is X and that in the surrounding seawater is Y then the concentration of that constituent at the surface, Z, will be given by

$Z= (X+DY)/(D+1)$, where D is the dilution, in this case 20-50.

For example, if the DO is 5.0 in the SS water and 8.0 in the ambient water then the DO at the surface above the SS will be 7.85 if the dilution is 20 and 7.94 if the dilution is 50. It is for this reason that the DO and pH measured above the SS are indistinguishable from the ambient water at control locations. By a similar calculation, if the SS water has a salinity of 4 and the ambient water 34, then the salinity immediately above the SS will be between 32.5 and 33.4, again very little different from the ambient water, but enough for about 2 sigma units (two parts per thousand) difference in density. In all likelihood the diluted SS water would float on the surface of the ocean if the wind and wave climate were very low, in which case the diluted plume water would leave the site as a surface flow. If the wave and wind climate were up the surface layer would mix rapidly through the water column and become completely indistinguishable from the ambient waters.

As previously discussed in Section 3.1, calculations show that the plume discharge at the shoreline is likely of the order of 800 meters or more wide, so that if all the effluent were uniformly distributed over this section of the coastline, and based on the current average effluent injection rate of 2.8 mgd (10,600 m^3/d), the seepage flow is of approximately 13 m^3/d/ per meter of coastline. (*i.e.*, about 9 liters/minute/meter of coastline, or roughly equivalent to a running garden hose per meter of coastline). By comparison, and according to the *Report*, Table 3.6a, the freshwater discharges at N. and S. Honokowai beaches are estimated to be 46 and 65 m^3/m/d, respectively.

The ultimate fate of the diluted SS water and effluent released over the diffuse interface between the ocean and fresh water is governed by the alongshore currents. Ocean currents close to shore generally follow the bottom topography and are driven by tides and wind. Although there does not appear to be any available current meter data for the site to provide a definitive measure of the current magnitudes and direction, there is a belief that the net current is toward the southeast, i.e., toward the Black Rock Lagoon. However, according to Storlazzi and Field (2008): "When the trade winds wane or the wind direction deviates from the dominant northeast trade wind orientation, strong alongshore currents flow to the northeast, into the dominant trade wind direction, and lower turbidity is observed both on the reef flat and over the fore reef." On these occasions the plume would be carried northeast and Black Rock Lagoon water would flow over Kahekili Beach.

A recent study by Dailer *et al.,* (2012) used macroalgae samples to integrate, over 7 days in February, April, May and June, the exposure to concentrations of the stable isotope N15 at Kahekili Beach, which is, as noted in **Table 3,** elevated in the SS discharges. The results of that study, presented in Figure 4 of the publication and reproduced here as **Exhibit 18**, also show the immediate dilution and transport of the nutrients in the SS discharges. The results of that study for February and April also show that higher fractions of N15 exist on the southern boundary of Kahekili Beach. The source of these higher concentrations does not appear to be the SS discharges and a clue to the possible source is given by the data in **Tables 3 and 11,** where it is evident that the waters of Black Rock Lagoon, located immediately to the south of the site of the Dailer *et al.* study area, have nitrogen and phosphorus concentrations of the same order, if not higher than, the SS and also have elevated $\delta^{15}N$

levels. The Dailer studies apparently did not incorporate any current meter data but, as noted by Storlazzi and Field (2008), on occasion there are strong currents towards the northeast. The data from the February study shown in **Exhibit 18** would suggest just such an event during that time. The data from the April study also suggest the presence of discharge from Black Rock Lagoon at that time.

The available data therefore indicate that the dilution and transport away from the site of effluent nutrients seeping into the coastal waters is very effective, and so much so that the waters of Kahekili Beach meet Hawaii water quality standards (WQS), except for turbidity, for Wet Coast Class A Ocean Waters and are being considered for classification as unimpacted (State of Hawaii, 2014, p. 33).

3.3(g) Fraction of effluent in submarine springs

One of the conclusions of the *Report*, based on the results of a tracer study using a dye BTC analysis, is that 68% of the total groundwater discharged from two SS areas is the treated wastewater injected at the LWRF and that 64% of the treated wastewater injected into the wells discharges from the SS areas (Glenn, *et al.* 2013, p. ES-16, ES-3). A second conclusion, based on a geochemical/stable isotope source water partitioning analysis, is that treated wastewater from LWRF contributes on average 62% of water discharged from the SS areas (Glenn, *et al.* 2013, pp.ES-3, ES-16). We examine each of these analyses.

3.3(g).1 Flow estimate based on breakthrough curve analysis

The BTC analysis estimated that 64% of the FLT dye injected at LWRF was recovered at the two SS areas. Using the injection rate of 2.47 mgd at LWRF and the 64% recovery rate, it was calculated that the average delivery rate of the LWRF treated wastewater at the two SS areas was 1.58 mgd (= 2.47 mgd × 64%), which was 68% of the 2.32 mgd estimated total SGD from the submarine springs (the *Report*, p. ES-16). The *Report* actually states: “That is, since the volume of treated wastewater at the submarine springs was 1.58 mgd (5,978 m3/d), the treated wastewater fraction of the 2.32 mgd (8,800 m3/d) total SGD from the submarine springs is 68 percent.” However, in reading the text (p. 4-21): “…. to estimate that 68% of the SGD at submarine springs and surrounding areas [emphasis added] is Wells 3 and 4 injectate.” The summary leaves the impression that the effluent is being discharged from the springs, when in fact the estimate is based upon spring flow and diffuse seepage over a much broader area. In any case, there are a number of difficult-to-justify assumptions that were made in this analysis.

The EPA model QTracer2 was used to analyze the BTCs at the NSG and the SSG, and to calculate the amount of dye recovered from the two seep group areas. Tracer dye concentrations and fresh groundwater discharge rates associated with the dye plume are two important inputs to the QTracer2 model to calculate the tracer dye recovery rate, which was in turn used to estimate the fraction of treated wastewater in the total SGD from the SS. There are issues with both of these two inputs to the analysis.

To understand the issues with the BTC calculations, it is important to note that the total SGD consists of SS discharges and diffuse discharge spread over a section of coastline that we estimate to be at least 800 m long (see Section 3.1). In **Exhibit 14** (Figure ES-4 of the *Report*), the total SGD corresponds to the groundwater discharge within the black boxes, and the SS discharges are groundwater flow through discrete points (colored circles) within the black boxes. Groundwater discharged through the SS is less than 10% of the total SGD in areas within the two black boxes, while diffuse discharge contributes more than 90% of the total SGD (the *Report*, pp. ES-2, ES-11). The four most important variables affecting the calculated amount of tracer dye recovered are: SS discharges, SS dye concentration, diffuse discharge and diffuse discharge dye concentration. As noted in **Exhibit 14**, the actual area of SS discharges is less than one third of a square meter but the 283 identified SS are encompassed in an area of 2300 m^2, whereas the diffuse seepage area is defined to be 10,180 m^2, but as seen in **Exhibit 15** is likely to be very much larger.

The major problem with the BTC calculations is that the BTCs were derived from dye concentrations measured at only a few SS discharges, yet these SS discharge BTCs and the total SGD (*i.e.*, SS and diffuse discharges combined) were used to calculate the total dye recovered. This means that dye concentrations of the diffuse discharge were assumed to be the same as the SS discharges. However, data showed that dye concentrations of the diffuse discharge were significantly lower than SS dye concentrations, and therefore the assumption that dye concentrations were the same for the SS discharge and the diffuse discharge is seriously flawed. Details on the issues of the dye recovery calculations in the *Report* are described in the sections below.

3.3(g).1.1 Tracer dye concentrations

Tracer dye (FLT) concentrations were regularly monitored at a few individual seeps (springs) at both the NSG and SSG during the study period, and were used to derive the BTC for each spring group, which is an input to the model QTracer2. The NSG consists of 183 seeps (springs) within an area of 1,800 m^2 (*Report*, p. ES-2). Tracer dye concentrations were monitored from time to time at 17 out of the 183 seeps in the NSG, and no more than 3 seeps were monitored at the same time. All monitored seeps were within an area of about 9 m^2 (*Report*, Figure 4-1), which is only 0.5% of the total area of 1,800 m^2. It is not clear whether the FLT concentrations obtained from such a small fraction of the total area can be used to represent the FLT concentrations of all seeps in the NSG. Monitoring of tracer dye concentrations at the SSG had the same problem. The SSG has 106 seeps within an area of 500 m^2 (*Report*, p. ES-2). However, dye concentrations were monitored at only four seeps within an area of about 4 m^2 (*Report*, Figure 4-1), which is less than 1% of the total area of 500 m^2. Samplings of submarine springs covering the entire NSG and SSG areas were only conducted once during a submarine spring survey in July, 2012. Data from the survey (*Report*, Table A-6) indicated that tracer dye concentrations of the seeps in the SSG were generally within a reasonable range (23.8 – 29.4 ppb) and were close to the dye concentrations at the regularly sampled SSG seeps, but dye concentrations of the seeps in the NSG spread over a broader range (2.3 – 26.1 ppb), excluding a few extreme data points. The large range of dye concentration at the NSG seeps indicates that sampling NSG springs within a small area is not likely to produce a representative BTC for the NSG.

More importantly, groundwater discharge from these submarine springs was less than 10% of the total groundwater discharge; more than 90% of the total groundwater discharge was through diffuse groundwater discharge (*Report*, pp. ES-2, ES-11). Very limited tracer dye data were available for the diffuse discharge, the samplings of which were far too sparse to derive a BTC for this discharge. However, these data did show that tracer dye concentrations of the diffuse discharge were much lower than those of the spring discharges. For example, the tracer dye concentration from a diffuse discharge sample collected on 7/13/2012 (Sample 60, Table A-6, p. A-58 of the *Report*) was 2.82 ppb, while on the same day, the tracer dye concentration was 19.9 ppb at Seep 17 (Table A-6, p. A-59 of the *Report*), which was about seven (7) times the dye concentration of the diffuse discharge sample (*i.e.*, the diffuse discharge dye concentration was less than 15% of the spring discharge concentration). The dye concentration of another diffuse discharge sample collected on 7/10/2012 (Sample 48, Table A-6, p. A-49 of the *Report*) was even lower, at 0.88 ppb. The specific electrical conductivity (SEC) of Sample 60 and Sample 48 were 50,810 µs/cm and 50,530 µs/cm, respectively. Although the *Report* stated that adjusted FLT dye concentrations were considered suspect for values of SEC greater than 50,000 µs/cm (*Report*, p. 4-28), these data should raise concerns that diffuse discharge dye concentrations were likely significantly lower than the concentration of spring discharges. The 50,000 µs/cm SEC value should not be considered an exact threshold to judge whether a data point is valid or not. In fact, most grab samples presented in Table A-6 of the *Report* had SEC values higher than 50,000 µs/cm.

Groundwater discharged through the diffuse flow could have flow paths different from those of the spring discharges, leading to different FLT concentrations. Therefore the BTCs derived from tracer dye data measured from a few spring discharges should not be applied to the diffuse discharge. Unfortunately the *Report* did use BTCs derived from FLT concentrations at a few submarine springs to represent the total SGD, including both the spring and diffuse discharges, which made the 64% calculated tracer dye recovery rate not meaningful.

3.3(g).1.2 Fresh groundwater discharge rate

The BTC analysis used a constant fresh groundwater discharge rate of 0.51 mgd (1,752 m^3/d) for the NSG over an integration period of more than 2,400 days, and a constant groundwater discharge rate of 1.4 mgd (5,439 m^3/d) for the SSG over an integration period of more than 2,000 days. It is unlikely that the fresh groundwater discharge rate could remain constant at NSG and SSG over such long time periods. In fact, data in Table 5-4 of the *Interim Report* showed that the SSG fresh groundwater discharge estimated from Seep 4 was 4,600 m^3/d and 7,800 m^3/d for June and September 2011, respectively; and the NSG fresh groundwater discharge estimated from Seep 6 was 1,800 m^3/d and 3,100 m^3/d for June and September 2011, respectively. The September 2011 discharge rates were approximately 70% higher than the June 2011 values, demonstrating that the groundwater discharge rate is highly variable over time. On a shorter time scale, it was observed that the groundwater discharge varied over tidal cycles: discharge increased during ebb tides and decreased during flood tides (the *Report*, p. ES-10). Therefore, it is not appropriate to use a constant fresh groundwater discharge rate in the BTC analysis, and the 64% dye recovery rate calculated from the BTC analysis is not at all accurate.

The fresh groundwater discharge rates (0.51 mgd for NSG and 1.4 mgd for SSG) used in the BTC analysis were calculated from SGD estimated from radon activity surveys. The equation for this calculation is listed as Equation 4-3 in the *Report* (p. 4-20). The salinity value used in Equation 4-3 of the *Report* was 12.6 for the NSG and 7.46 for the SSG, which are much higher than the average salinity of 3.1 used in the FLT BTC concentration adjustment (*Report*, Equation 4-1, p.4-17). This means that two different salinity values were used for the same SGD, which is not consistent. The *Report* needs to discuss why these high salinity values, instead of the salinity of 3.1, were used in Equation 4-3.

A more important question about the fresh groundwater discharge rate is which groundwater discharge rate should be used in the BTC analysis to calculate the tracer dye recovery rate. The total dye tracer recovered along the coast should be composed of dye recovered from the spring discharge and the diffuse discharge, as shown in the equation below.

Total Dye Recovered = Dye Recovered from Springs + Dye Recovered from Diffuse Discharge

Thus, the general way of calculating the total dye recovered is to use the spring dye BTC and spring groundwater discharge to compute dye recovered from spring discharges, and use the diffuse dye BTC and diffuse groundwater discharge to compute dye recovered from the diffuse discharge. The two parts can then be summed to yield the total dye recovered. If the spring dye BTC is exactly the same as the diffuse dye BTC, the total dye recovered can be calculated from the spring dye BTC and the total SGD, which is the method used in the *Report*. However, as described in the prior section, dye concentration data for the diffuse discharge clearly showed that the diffuse discharge had much lower dye concentrations than the spring discharge. Therefore, the method used in the *Report* to calculate dye tracer recovery rate is not correct, and the calculated 64% dye recovery rate is not meaningful.

3.3(g).1.3 Uncertainty in dye recovery rate calculations

The major variables used in dye recovery rate calculations are measured dye concentrations and groundwater discharge rates, and data have shown that both variables have significant spatial and temporal variations. It is impractical and impossible for the monitoring program to accurately capture all fluctuations in tracer concentrations and groundwater discharge, as shown in the USGS studies (Swarzenski *et al*., 2011). Therefore, the dye recovery rate calculations inevitably have high uncertainties, which have been acknowledged in the *Report*.

"The estimated percent of dye mass recovered can also be used to make estimates of the fraction of treated wastewater in the submarine spring discharge, although it must be stressed that there are significant uncertainties associated with these calculations" (*Report*, p. 4-20).

"There is significant uncertainty associated with the effluent percentage estimated by this method due to the assumption of a uniform FLT concentration over the entire area that the radon SGD estimates were based upon, the variability of SGD flux with time, and variability of the fraction of FLT plume water over the area used in these computations" (*Report*, p. 4-21).

However, these statements about the significant uncertainties in the calculations are not included in the Executive Summary of the *Report*. It is imprudent and misleading to present the calculated 64% dye recovery rate in the Executive Summary of the *Report* without stating the significant uncertainty associated with the calculations. For calculations with significant uncertainty, some additional analyses are usually performed to quantify the uncertainty or to provide a range of possible results. Unfortunately the *Report* made no effort to analyze the uncertainty in the dye recovery rate calculations.

Because of the significant uncertainty associated with the dye recovery rate calculations, it is more reasonable to present a range for the dye recovery rate rather than just a single value, and this range can be quite large. To give an example of a possible dye recovery rate, a different estimation method is used here, which calculates the dye recovered from the spring discharge and the diffuse discharge separately.

To estimate dye recovered from the spring discharge, the same BTC data sets as used in the *Report* were used as an input to the model QTracer2, but instead of the total fresh groundwater discharge rates, the spring fresh groundwater discharge rates, 194 m^3/d for the NSG and 69 m^3/d for the SSG (*Report,* Table 3-4), were used. The calculated tracer dye recovery rate for the spring discharge was approximately 1.6% at the NSG and 0.6% at the SSG, giving a total spring tracer dye recovery rate of 2.2% from all of the springs in the NSG and SSG (excluding the diffuse discharge).

Dye concentration data for the diffuse discharge were too sparse to derive a BTC, and as a result, dye recovered from the diffuse discharge can only be estimated roughly. The limited data for the diffuse discharge showed that dye concentrations of the diffuse discharge were less than 15% of the spring discharge. Assuming the diffuse discharge dye concentration was 15% of the spring discharge dye concentration, and using the diffuse fresh groundwater discharge rates of 1,558 m^3/d (= 1752 -194 m^3/d) for the NSG area and 5,370m^3/d (= 5439 – 69 m^3/d) for the SSG area, the dye recovery rate for the diffuse discharge was estimated from the equation below.

$$\begin{aligned}
R_d = \; & R_{d-NSG} + R_{d-SSG} \\
& = \frac{\int Q_{d-NSG} C_{d-NSG} dt}{M} + \frac{\int Q_{d-SSG} C_{d-SSG} dt}{M} \\
& \approx \frac{0.15 Q_{d-NSG}}{Q_{s-NSG}} \frac{\int Q_{s-NSG} C_{s-NSG} dt}{M} + \frac{0.15 Q_{d-SSG}}{Q_{s-SSG}} \frac{\int Q_{s-SSG} C_{s-SSG} dt}{M} \\
& \approx \frac{0.15 Q_{d-NSG}}{Q_{s-NSG}} R_{s-NSG} + \frac{0.15 Q_{d-SSG}}{Q_{s-SSG}} R_{s-SSG} \\
& = \frac{0.15 \cdot 1558}{194} \cdot 0.016 + \frac{0.15 \cdot 5370}{69} \cdot 0.006 \\
& = 0.019 + 0.070 \\
& = 0.089 \\
& = 8.9\%
\end{aligned}$$

In the equation above, *R* denotes dye recovery rate, *Q* is fresh groundwater discharge rate, *C* is dye concentration, and *M* is the mass of total injected dye tracer; the subscript *d* means diffuse discharge; *d-NSG* and *d-SSG* are diffuse discharges in the NSG and SSG areas, respectively; and *s-NSG* and *s-SSG* are spring discharges in the NSG and SSG areas, respectively.

The dye recovery rate for the diffuse discharge was estimated to be about 8.9% from the above calculations. Combining the dye recovery rate for the spring discharge and the diffuse discharge yields a total dye recovery rate of about 11%. Using the injection rate of 2.47 mgd and the 11% dye recovery rate, the average delivery rate of the LWRF treated wastewater at the two submarine spring areas is calculated to be 0.27 mgd, which is about 12% of the 2.32 mgd total SGD from the submarine spring areas.

Again, it should be noted that the uncertainties in these calculations are significant, which is mainly a result of limited data availability, especially for the diffuse discharge. The purpose of the calculations above is not to determine accurately the dye recovery rate, but rather to demonstrate that the calculated dye recovery rate can vary over a wide range when different but plausible assumptions were used in the calculations. Additional analyses need to be performed to quantify the uncertainties in the dye recovery rate calculations. For calculations with significant uncertainties, it is not meaningful to just present the results without analyzing the associated uncertainties.

3.3(g).2 Geochemical/stable isotope analysis of treated wastewater to the ocean

The fraction of the LWRF treated wastewater in groundwater discharged in the NSG and SSG areas was also estimated through a geochemical/stable isotope mixing analysis, as presented in Section 6.4.2.3 of the *Interim Report*. That analysis also has some serious flaws, which are discussed in the sections below.

3.3(g).2.1 Water sources for the submarine spring discharge

In the geochemical/stable isotope mixing analysis, the SS discharge was assumed to be a mixture of upland groundwater, LWRF treated wastewater effluent, and marine waters (*Interim Report*, p.157). Water samples were collected for all three water sources for the geochemical/stable isotope mixing analysis. The major problem in this process is that the sampling locations for upland groundwater, located about 3-5 km from shoreline, are far inland. The area between shoreline and the upland sampling locations, shown within the red line in **Exhibit 19** below, is more than 15 km^2. In this large area, water from sources other than the three assumed ones can also contribute to the SS discharge. For example, precipitation within this area, especially on the plantation lands[14], can infiltrate into ground and discharge at the SS. Phosphorus data shown in Tables ES-2 and ES-3 of the *Report* (pp. ES-23, ES-24) also indicate that the SS must have sources of phosphorus other than in the three assumed sources. The average phosphorus concentration in the SS discharge samples was much higher than in the three assumed sources (i.e., upland groundwater in production wells, treated wastewater, and marine waters). If the SS discharge is a mixture of water from only the three assumed sources, its phosphorus concentration cannot be higher than the source with the highest phosphorus concentration, unless there are other sources with high phosphorus contributing to the SS discharge (see Section 3.2 for prior discussion of phosphorus sources). It is clear that the assumed three water sources do not include all water sources contributing to the SS discharge. The very fundamental assumption of the geochemical/stable isotope is seriously flawed. Therefore, the results of this analysis are not meaningful.

3.3(g).2.2 Method and results of the geochemical/stable isotope mixing analysis

The generally conservative isotopes ^{18}O, ^{2}H and the ion Cl$^-$ were used as tracers for waters from the three assumed sources. Mixing analyses described in the *Interim Report* were conducted for (1) δ^{18}O and ^{2}H, (2) δ^{18}O and Cl$^-$, and (3) δ^{2}H and Cl$^-$ to estimate fractions of waters from the three sources in the SS discharge.

The geochemical/stable isotope analysis produced eighteen (18) total data sets for the SS samples, which are enclosed in blue boxes in **Table 12** (edited from Table 6-14 of the *Interim Report*) below. The highlighted nine (9) data sets failed to produce any meaningful results because the calculated fraction for one or more water sources is either negative or greater than 100%. The other nine data sets showed that the fraction of LWRF effluent ranged from 12 to 96 percent, with an average of 62 percent, and these data were presented in Table ES-8 and plotted in Figure ES-9 of the *Report*. However, it is not scientific to present in the Executive Summary only the nine (9) within-bounds data

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[14] See http://pubs.usgs.gov/sir/2012/5010/sir2012-5010.pdf

sets. The nine (9) other data sets that yielded an unrealistic (>100% or <0%) fraction for one or more source waters in the SS discharge should not be simply ignored.

The fact that half of the total data sets failed to provide any meaningful results demonstrates that the geochemical/stable isotope analysis method is not reliable. Thus, the results obtained from this method are not meaningful. In addition, only six samples were collected from four SS, which is far too sparse a sampling to cover the spatial and temporal variations of the total SGD. In particular, there was no sample for the diffuse discharge, which accounted for more than 90% of the total SGD. Thus, the geochemical/stable isotope analysis suffers from the same flaw as the BTC analysis and produces results with significant uncertainties. In fact, the *Interim Report* clearly stated that these results were "by no means conclusive due to the relatively small sample sizes and sensitivity of this technique to end-member temporal variation and intra-sample component inconsistency" (*Interim Report*, p. 158). Also, as was discussed Section 3.3(d), using the salinity and temperature data within the SS indicated that the SS had something like 40 percent effluent, 50 percent upland ground water and 11 per cent sea water. A similar calculation for the diffuse seepage is not possible because of a lack of temperature and salinity data in the seeps.

The fundamental assumption of the geochemical/stable isotope analysis is therefore seriously flawed and the results of this analysis clearly demonstrate that the method is not reliable. The results from this geochemical/stable isotope analysis are therefore not meaningful and should not be used as a basis for estimating the fraction of LWRF effluent in the groundwater discharged in the SS areas.

Table 12 – Input Parameters and Results of the End-member Mixing Analysis

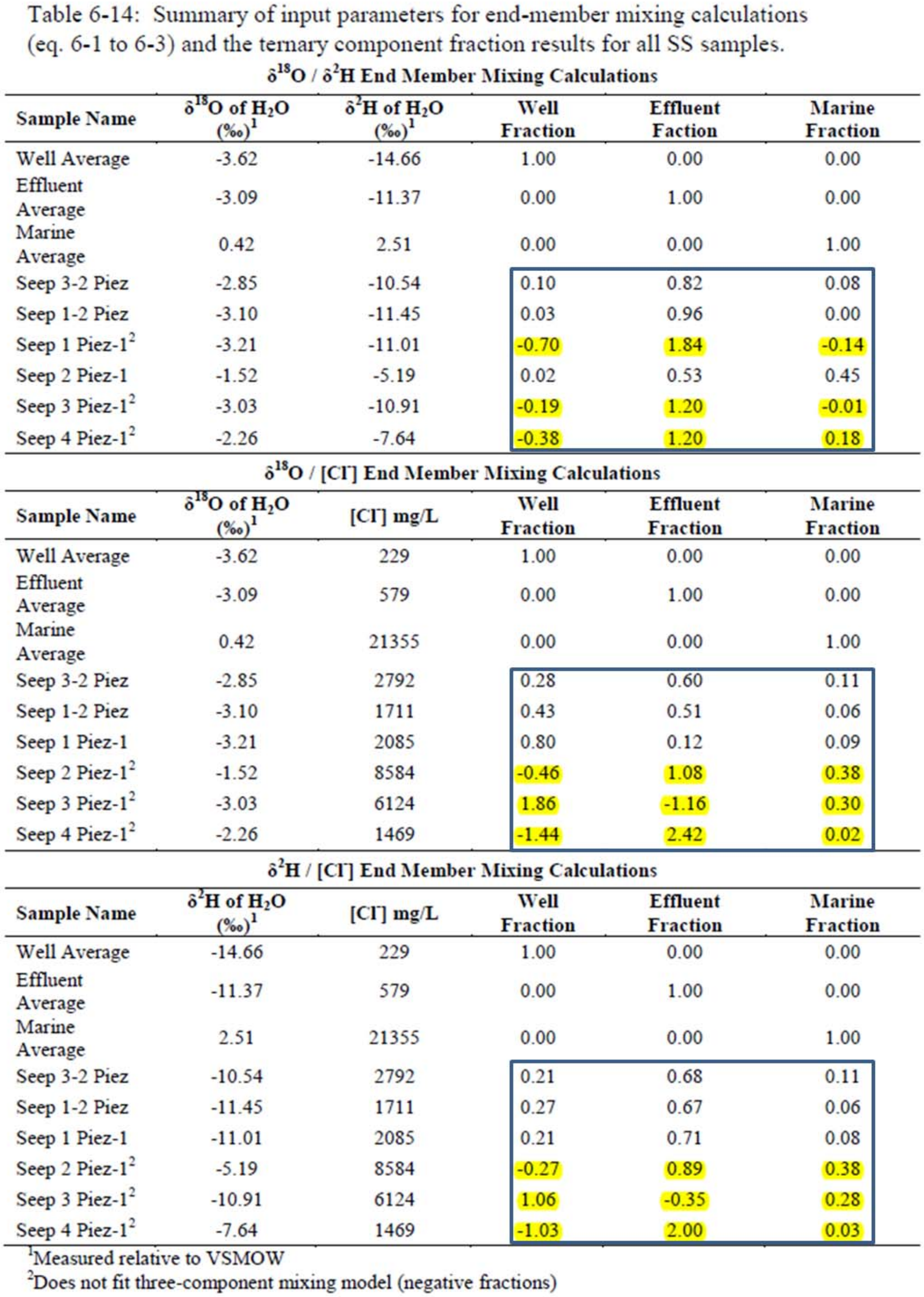

Table 6-14: Summary of input parameters for end-member mixing calculations (eq. 6-1 to 6-3) and the ternary component fraction results for all SS samples.

$\delta^{18}O$ / δ^2H End Member Mixing Calculations

Sample Name	$\delta^{18}O$ of H_2O (‰)[1]	δ^2H of H_2O (‰)[1]	Well Fraction	Effluent Faction	Marine Fraction
Well Average	-3.62	-14.66	1.00	0.00	0.00
Effluent Average	-3.09	-11.37	0.00	1.00	0.00
Marine Average	0.42	2.51	0.00	0.00	1.00
Seep 3-2 Piez	-2.85	-10.54	0.10	0.82	0.08
Seep 1-2 Piez	-3.10	-11.45	0.03	0.96	0.00
Seep 1 Piez-1[2]	-3.21	-11.01	-0.70	1.84	-0.14
Seep 2 Piez-1	-1.52	-5.19	0.02	0.53	0.45
Seep 3 Piez-1[2]	-3.03	-10.91	-0.19	1.20	-0.01
Seep 4 Piez-1[2]	-2.26	-7.64	-0.38	1.20	0.18

$\delta^{18}O$ / $[Cl^-]$ End Member Mixing Calculations

Sample Name	$\delta^{18}O$ of H_2O (‰)[1]	$[Cl^-]$ mg/L	Well Fraction	Effluent Fraction	Marine Fraction
Well Average	-3.62	229	1.00	0.00	0.00
Effluent Average	-3.09	579	0.00	1.00	0.00
Marine Average	0.42	21355	0.00	0.00	1.00
Seep 3-2 Piez	-2.85	2792	0.28	0.60	0.11
Seep 1-2 Piez	-3.10	1711	0.43	0.51	0.06
Seep 1 Piez-1	-3.21	2085	0.80	0.12	0.09
Seep 2 Piez-1[2]	-1.52	8584	-0.46	1.08	0.38
Seep 3 Piez-1[2]	-3.03	6124	1.86	-1.16	0.30
Seep 4 Piez-1[2]	-2.26	1469	-1.44	2.42	0.02

δ^2H / $[Cl^-]$ End Member Mixing Calculations

Sample Name	δ^2H of H_2O (‰)[1]	$[Cl^-]$ mg/L	Well Fraction	Effluent Fraction	Marine Fraction
Well Average	-14.66	229	1.00	0.00	0.00
Effluent Average	-11.37	579	0.00	1.00	0.00
Marine Average	2.51	21355	0.00	0.00	1.00
Seep 3-2 Piez	-10.54	2792	0.21	0.68	0.11
Seep 1-2 Piez	-11.45	1711	0.27	0.67	0.06
Seep 1 Piez-1	-11.01	2085	0.21	0.71	0.08
Seep 2 Piez-1[2]	-5.19	8584	-0.27	0.89	0.38
Seep 3 Piez-1[2]	-10.91	6124	1.06	-0.35	0.28
Seep 4 Piez-1[2]	-7.64	1469	-1.03	2.00	0.03

[1] Measured relative to VSMOW

[2] Does not fit three-component mixing model (negative fractions)

3.4 Plaintiffs' expert report

Plaintiffs' expert Dr. Moran has expressed a number of opinions that are seemingly either purposefully vague and general or are unsupported by the evidence available in this case. To be specific:

(1) *"…….wastewater injected into Wells 1 and 2 will behave in a manner similar to wastewater injected into Wells 3 and 4; i.e., it will travel quickly (on a timescale of months) to the adjacent, shallow ocean".*

Comment:
The statement: *"will behave in a manner similar to wastewater injected into Wells 3 and 4",* even conditioned by: *"i.e., it will travel quickly (on a timescale of months) to the adjacent shallow ocean"* is vague. In any case, it is contradicted by the *Report*, p. 4-38: *"...our study indicates the effluent from Well 2 may not be discharging into nearshore waters and a discharge point deeper and further from shore needs to be considered".* And also at p. 4-38 of report*: "We conclude that the primary cause for the non-detection of SRB is displacement of the SRB plume away from the submarine springs by injection into Wells 3 and 4. Also, due to the failure to positively detect SRB and inference (sic) with the SRB plume resulting from injection into Wells 3 and 4, no conclusions can be made regarding the hydraulic connection between Well 2 and the nearshore waters at Kaanapali."* In other words, the wastewater injected at Well 2, based on the empirical evidence, does not behave in a similar manner to wastewater injected at Wells 3 and 4.

(2) Dr. Moran further states that: "*The tracer test results unequivocally demonstrate that transport from the LWRF wells is via 'fast paths' through porous media of high hydraulic conductivity".*

Comment:
Dr. Moran as an experienced hydrogeologist knows full well that every heterogeneous aquifer has a very broad distribution of particle flow velocities, which occur because of the tortuosity and macroscopic variations in porosity and permeability of such a medium. It is this broad distribution of fluid particle velocities that generate the dispersion seen in the tracer BTC for any tracer introduced into a well, especially in an aquifer as heterogeneous as described in the driller's logs (**Exhibits 2 and 3**). Representation of this dispersion phenomenon requires very detailed knowledge on the macroscopic scale of the hydraulic conductivity variations; knowledge which is near impossible to acquire. In this case the BTC seen in the tracer dye studies is no different from many other BTCs seen in polluted ground waters and the existence of a 'fast' first arrival, a later peak concentration and a gradual tailing off in concentration are very typical. There is no specific 'fast path' that generates the BTC, it is entirely an artifact of the broad distribution of flow velocities that exist in an heterogeneous aquifer.

(3) *"The tracer dye study showed that groundwater velocities are a maximum of 31.2 ft/d [9.5 m/d] and a mean of 5.6 ft/d [1.7 m/d] ….. These are high groundwater velocities that substantiate a fast flow path."*

Comment:
The USGS (Gingerich and Engott, 2012) represent West Maui basaltic lava aquifers as having an average hydraulic conductivity in the range 600-900 (m/d) and a porosity of 0.1-0.2. Given the natural hydraulic gradient of 2-3 ft/mile (~0.0005) these aquifer parameters imply a mean pore velocity of about 2 m/d. A peak velocity of 9.5 m/d implied by the first arrival on the BTC either implies a hydraulic gradient of 0.0024 with a hydraulic conductivity of 600 m/d, which for a injection well 1200 m from the sea would mean a water surface elevation of 3.9 m (9.5 ft) above sea level, which is typical of the water levels in the injection wells. Or it means that the macroscopic distribution of hydraulic conductivity encompasses a broader range than 600-900 m/d, which would not be unusual. The distribution of flow velocities implied by the BTC is typical of what could be expected and there is no 'fast path'.

(4) *"Significant dilution of the wastewater is unlikely along a fast flow path and is especially unlikely for Well 2, which is most strongly influenced by an intersecting high K layer".*

Comment:
Dilution of the injected wastewater occurs at the point of injection since the wells penetrate the salt water layer beneath the island and also interact with the natural groundwater flow. Furthermore, very substantial dilution occurs where the effluent enters the ocean, as described in Section 3.3(e). The statement that dilution is especially unlikely for Well 2 is completely contradicted by the evidence---in two tracer dye studies the dilution has been so effective no one has been able to find the tracer introduced into Well 2.

(5) "*In my opinion, the MODFLOW/MODPATH model developed for the tracer dye study offers additional evidence for similar flowpaths from Wells 3 and 4 and Wells 1 and 2."*

Comment:
The graphics in the *Report* (see Figures 4-39a and 4-39b) completely contradict this statement. First, no modeling was done on Well 1. Second, the Well 2 flow in the modeling is estimated to spread substantially beyond the area delineated by the flow from Wells 3 and 4, regardless of whether Wells 3 and 4 are operating. Moreover, Wells 3 and 4 have operated a vast majority of the time relevant to this case so Well 2 flow paths would be wider spread during this time.

(6) " *Both introduced tracer and geochemical tracers show that approximately 65% of effluent from Wells 3 and 4 is observed in near-shore seeps*"

Comment:
There is no refernce to a 65% figure in the *Reports*. There are references to 68%, 64% and 62%. As shown in Section 3.3(g) of this report, the estimate of these percentages of the Wells 3 and 4 effluent being observed in the seeps plus diffusive seepage area is very problematic. There is no question that 100% of the effluent from Wells 3 and 4 will eventually reach the ocean—all freshwater on the island must ultimately mix into the ocean. As the tracer study showed, some of the effluent is discharged at the near-shore seeps, but as made clear in **Exhibit 14**, the fraction of freshwater discharged from the seeps at Kahekili Beach is but a very small fraction of the total freshwater discharge in the area.

(7) ”*- the main flowpaths for the majority of the wastewater were found using the tracer. The direction and rate of the majority of the flow are therefore well constrained by the tracer results”*

Comment:
The tracer appeared at concentrations of 20-30 ppb in the visible springs. The concentration of the tracer in the diffuse seepage area was a factor 7-10 less than in the indentified springs. Furthermore, the effluent from Well 2 could not be found. Since the springs only represent less than 8% of the freshwater discharges to the coastal zone examined the main flow paths of the majority of the flow were certainly not well constrained by the tracer results (see **Exhibit 14**).

(8) *“The results of the model run described on p.5-18 of Glenn at al. 2013) (in which Well 2 injecting at the rate that was recorded during the SRB tracer test and Wells 3 and 4 are dormant following the tracer injection can be used to make an estimate of the predicted first arrival time, peak arrival time, maximum tracer concentration and dilution factor for tracer from Wells 1 and 2 to the North Seep Group (NSG) and South Seep Group (SSG).”*

Comment:
The presumption here is that Wells 3 and 4 will be dormant, which is not the case. They represent approximately 50% of the injected effluent, so that with Wells 3 and 4 in operation the results of modeling with Wells 3 and 4 dormant have no relevance. Further, as discussed above, even with Wells 3 and 4 dormant, modeling shows that Well 2 injectate flows not only towards the springs area but also to the north up the coast.

(9) “*These model results are therefore further evidence that flow and transport from Wells 1 and 2 is similar to flow and transport from Wells 3 and 4.”*

Comment:
The model results when Wells 3 and 4 are in operation, which is essentially all the time, make it clear that the flow and transport from Wells 1 and 2 is completely different from Wells 3 and 4 (see Figures 4-39a and 4-39b, *Report*). Moreover, even when Wells 3 and 4 are off, the model estimates Well 2 flow will be more broadly dispersed than flow from Wells 3 and 4.

(10) *“Other tracer methods (nitrogen isotope ratio ($\delta^{15}N$), heat, salinity, algae sampling) capture conditions over different and somewhat longer time periods compared to the tracer study, and these time integrated methods show the effects of wastewater discharge in the same area as tracer detections.”*

Comment:
The only time integrated method of analysis was the placement of macroalgae samples as described in Dailer *et al*., (2012). Dailer’s data showed that additional sources of nitrate with elevated N^{15} were present at Kahekili Beach (see Section 3.3(f) and **Exhibit 18)**. As shown in Section 3.3(d) heat has been shown to be of purely geothermal origin and cannot be used as a tracer for effluent. Reduced salinity in the coastal zone of an island is simply a function of island hydrology, as is evident in Table 3-5a of the *Report.*

3.5 References

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4. Exhibits used to support the opinions expressed.

(Note that the following will be used as exhibits, as will excerpts from the documents referenced in this report, data relied on in this report, and data and documents relied on by Dr. Moran.)

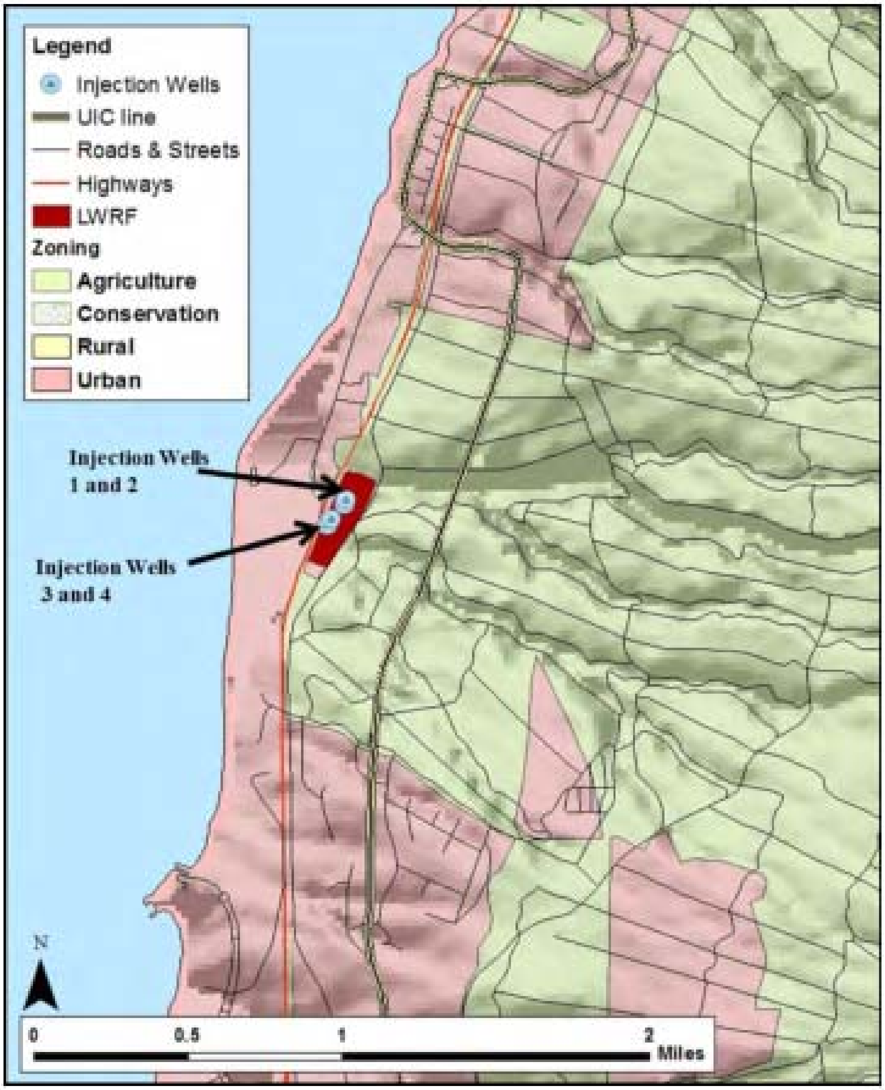


Figure 1-3: Location of the LWRF in relation to the coast and the UIC line. LWRF Injection Wells 1 and 2, which receive the majority of treated wastewater effluent, lie to the northeast of Wells 3 and 4.

Exhibit 1 – Location of injection wells 1, 2 3 and 4 (*Report*, p. 1-20)

(Note that statement in the figure legend concerning Wells 1 and 2 receiving majority of treated wastewater effluent is not consistent with the data in Exhibit 4.)

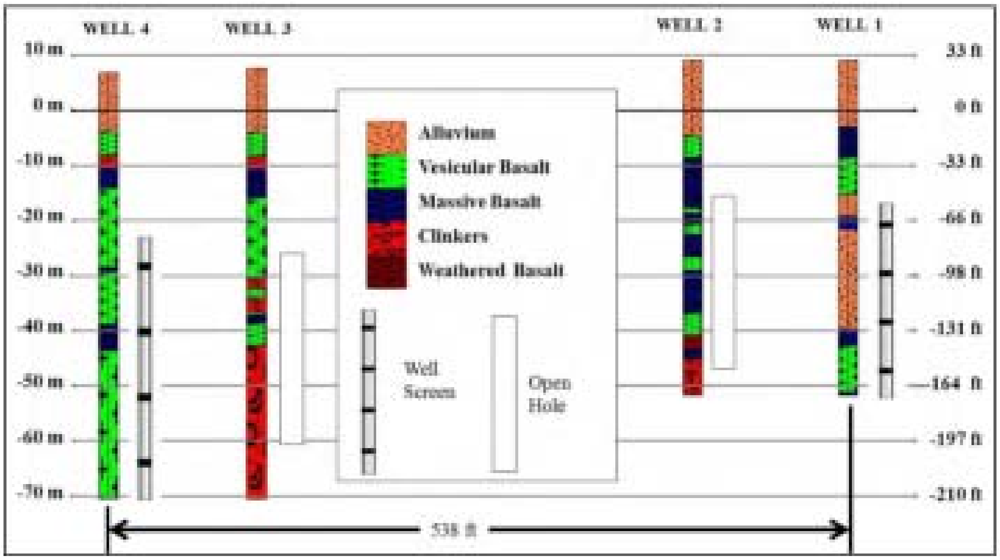
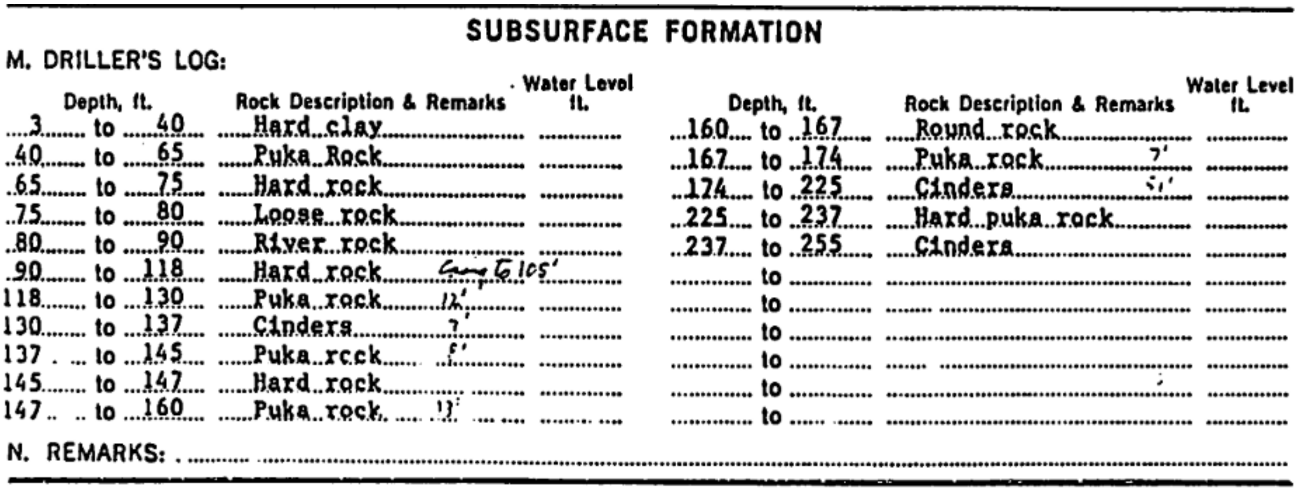


Figure 1-4: Borehole stratigraphy for the LWRF injection wells developed from the drillers' logs. (County of Maui, 2004)

Exhibit 2 – Injection well stratigraphy and screening (*Report*, p. 1-21).



SUBSURFACE FORMATION

M. DRILLER'S LOG:

Depth, ft.		Rock Description & Remarks	Water Level ft.	Depth, ft.		Rock Description & Remarks	Water Level ft.
3	to 40	Hard clay		160	to 167	Round rock	
40	to 65	Puka Rock		167	to 174	Puka rock 7'	
65	to 75	Hard rock		174	to 225	Cinders 51'	
75	to 80	Loose rock		225	to 237	Hard puka rock	
80	to 90	River rock		237	to 255	Cinders	
90	to 118	Hard rock Casing to 105'			to		
118	to 130	Puka rock 12'			to		
130	to 137	Cinders 7'			to		
137	to 145	Puka rock 8'			to		
145	to 147	Hard rock			to		
147	to 160	Puka rock 13'			to		

N. REMARKS:

Exhibit 3 – Injection well driller's log.

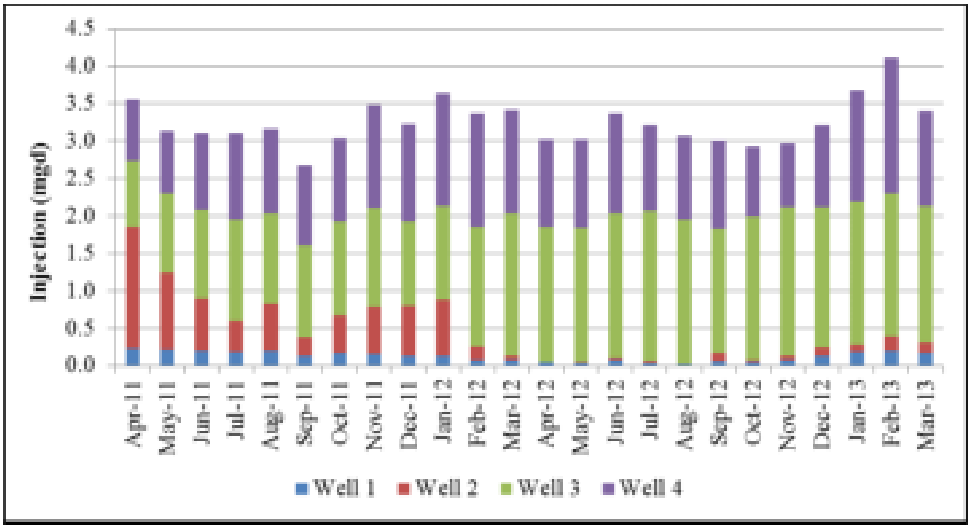


Figure 1-5: Monthly average injection at the LWRF. (County of Maui, 2011; and County of Maui, 2012-2013)

Exhibit 4 – Monthly average injection 4/11-3/13 (*Report*, p. 1-21).

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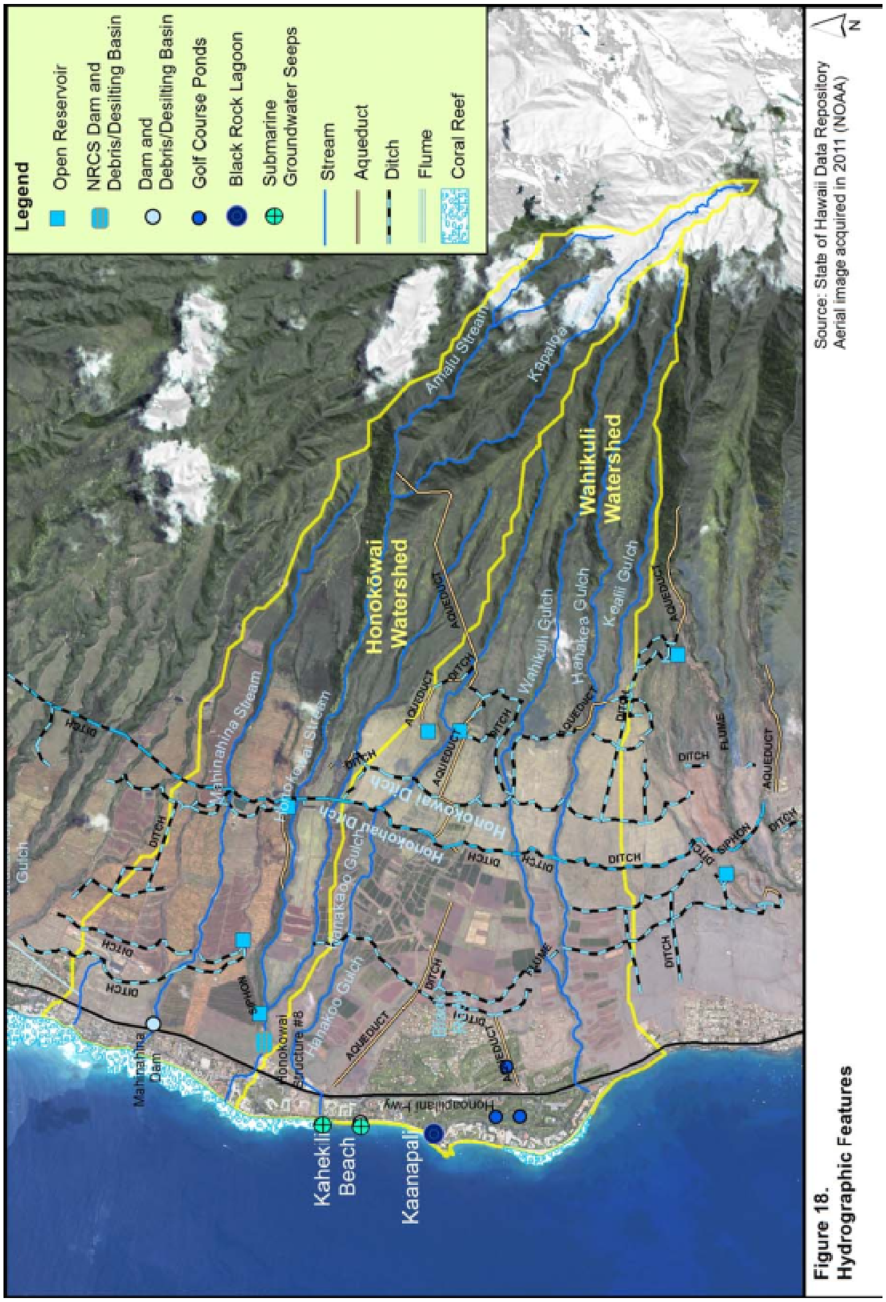


Exhibit 5 – Hydrographic features of watershed for Kahekili Beach (WMP, 2012).

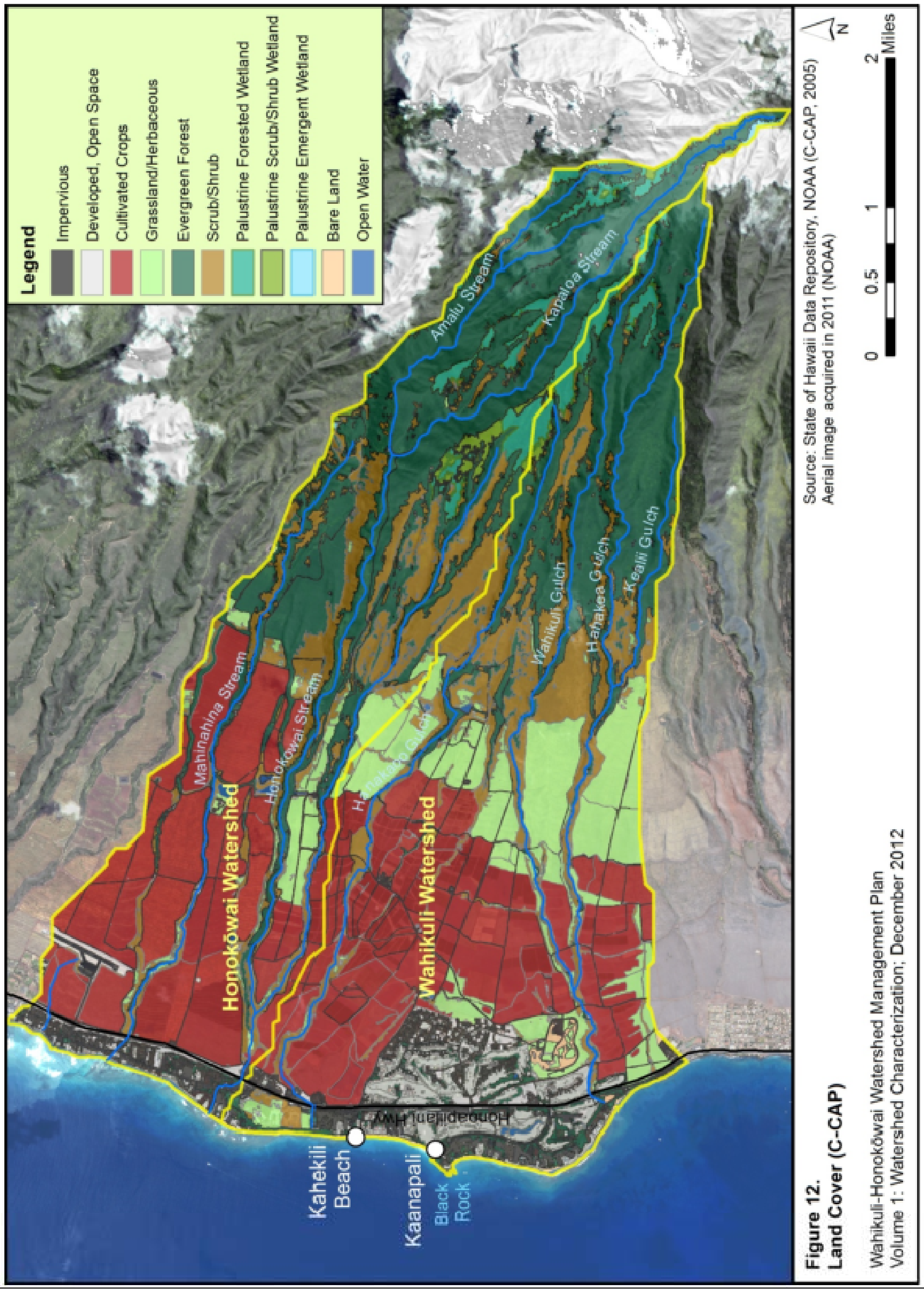
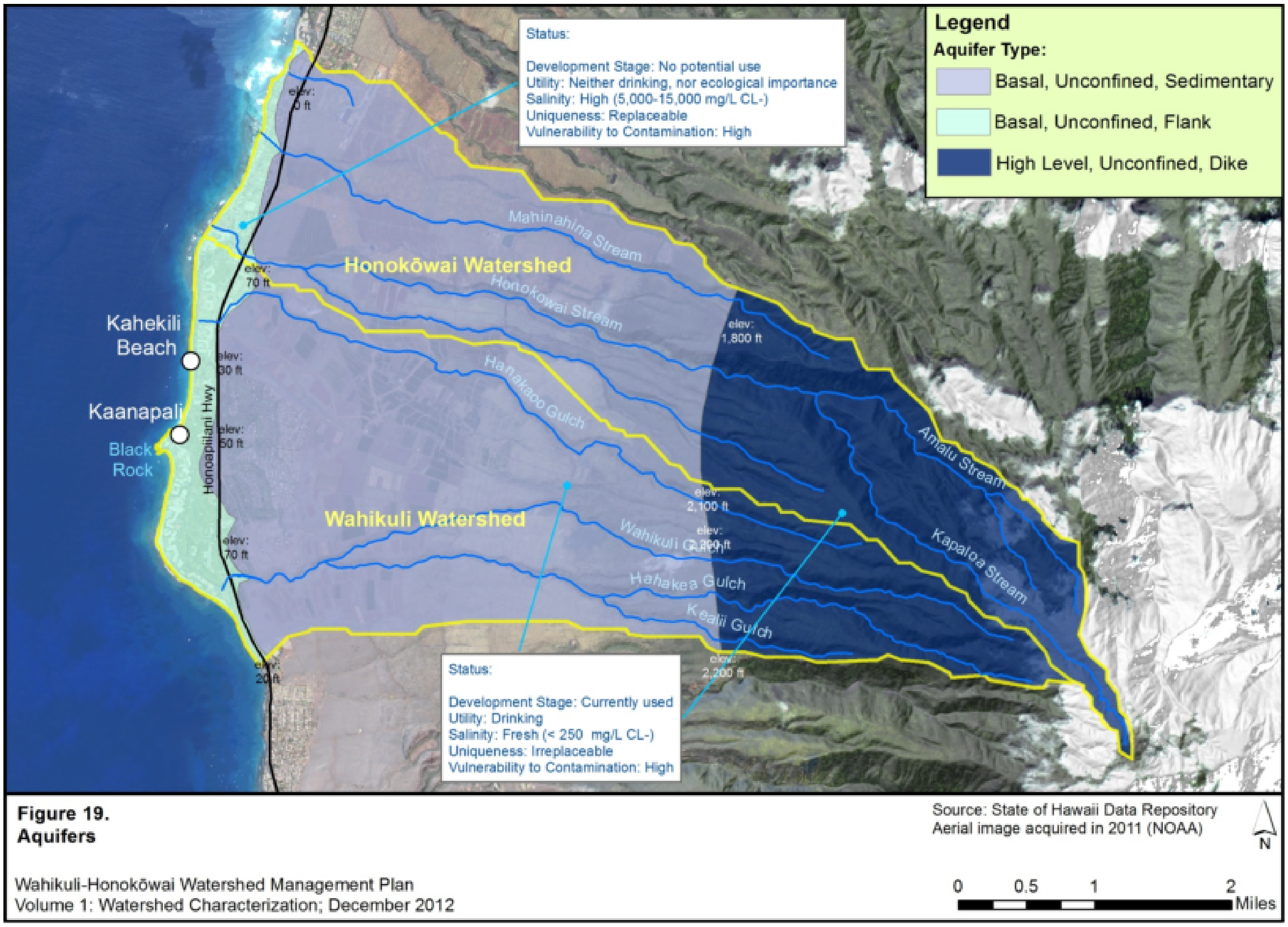


Exhibit 6 – Upland land use Wahikuli watershed (WMP, 2012).

Exhibit 7 - Satellite photo showing upland undeveloped agricultural land.



Status:

Development Stage: No potential use
Utility: Neither drinking, nor ecological importance
Salinity: High (5,000-15,000 mg/L CL-)
Uniqueness: Replaceable
Vulnerability to Contamination: High

Status:

Development Stage: Currently used
Utility: Drinking
Salinity: Fresh (< 250 mg/L CL-)
Uniqueness: Irreplaceable
Vulnerability to Contamination: High

Figure 19.
Aquifers

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Exhibit 8 – Watershed aquifers (WMP, 2012)

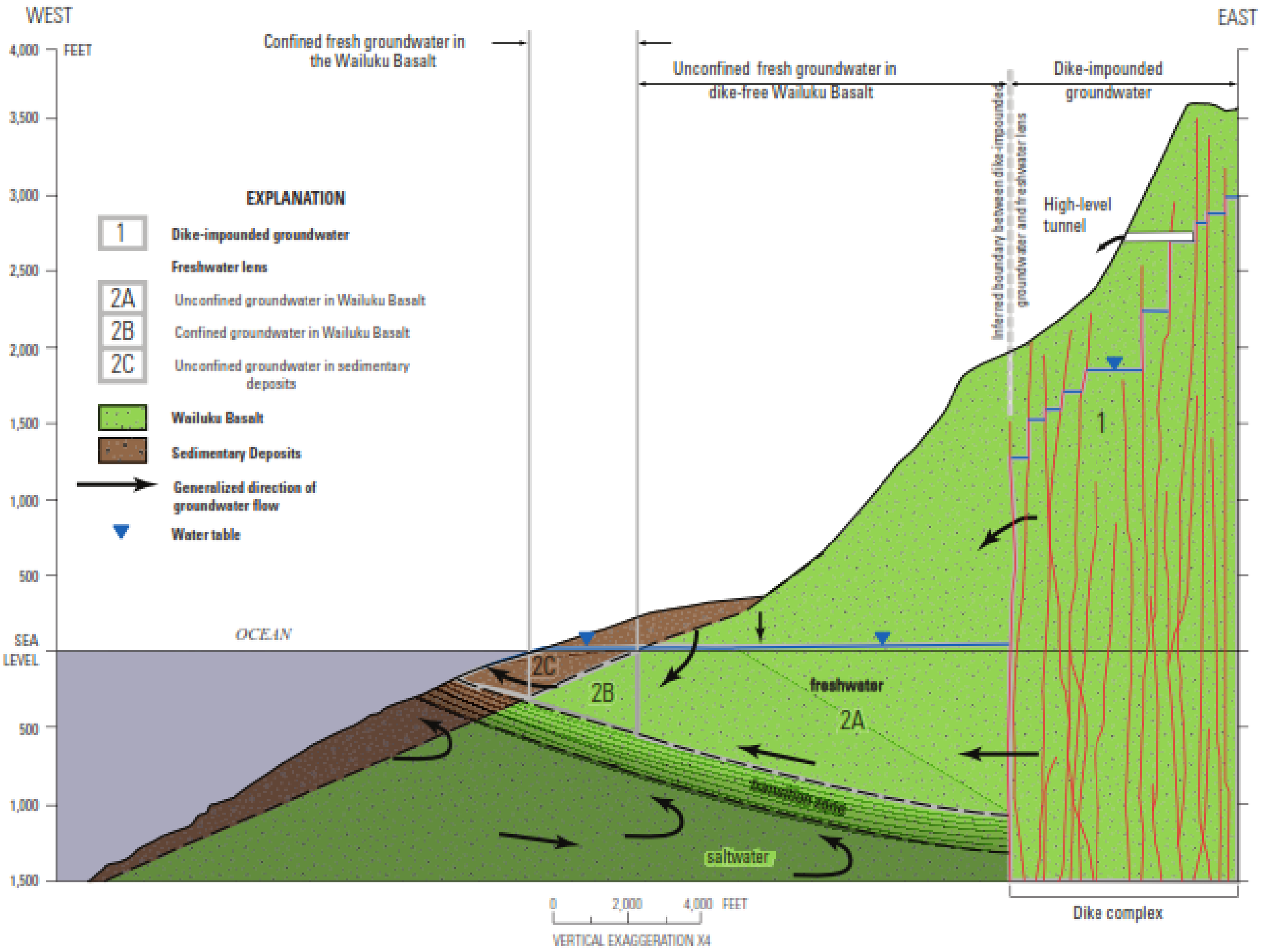


Figure 7. Geologic section of the Lahaina area showing groundwater occurrence and movement, west Maui, Hawai‘i.

Exhibit 9 – Geologic section of the Lahaina area (Gingerich and Engott, 2012). (Note that saltwater layer as depicted is much deeper at the shoreline than appears in the LWRF injection wells shown in Figure 13 of the referenced document).

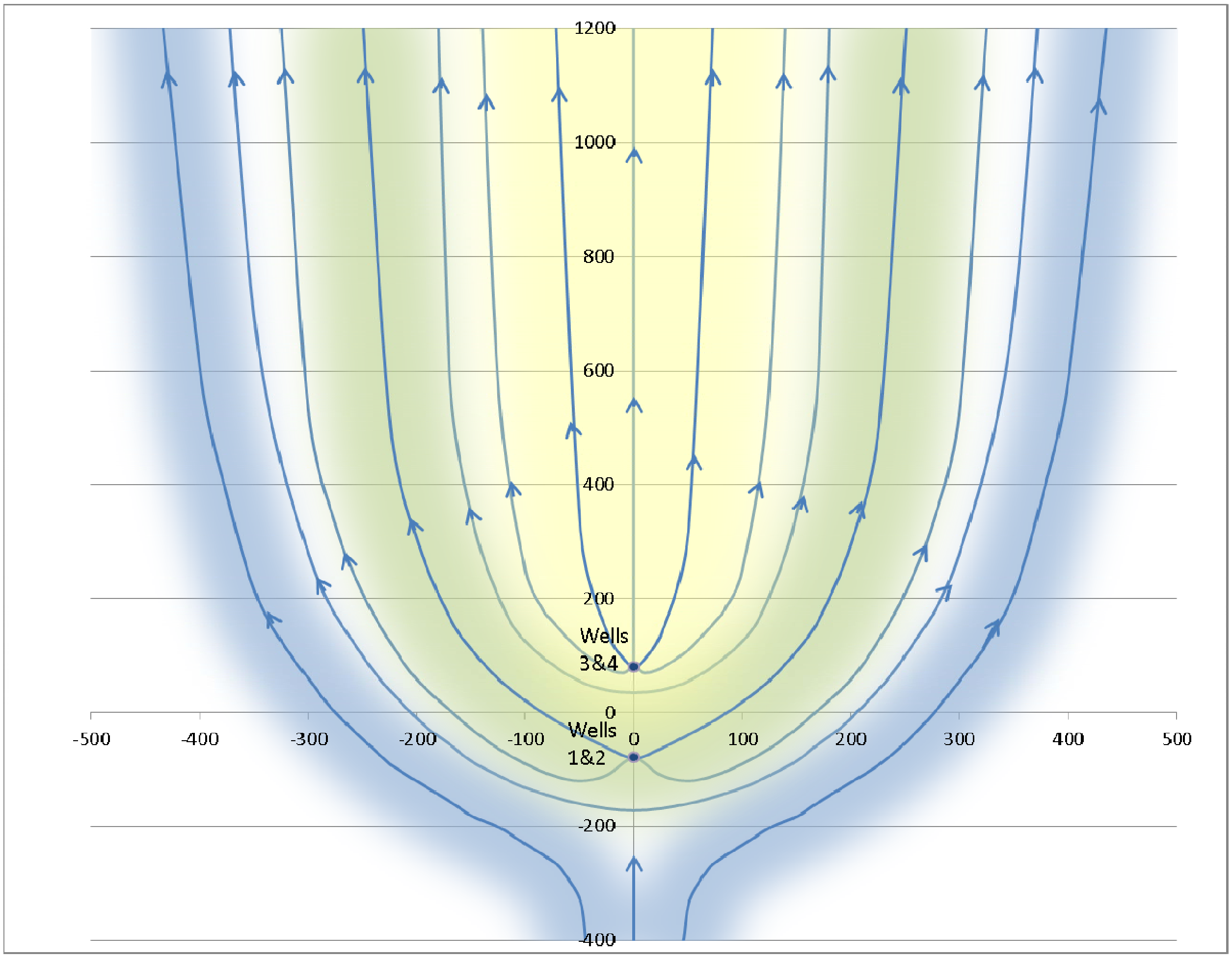
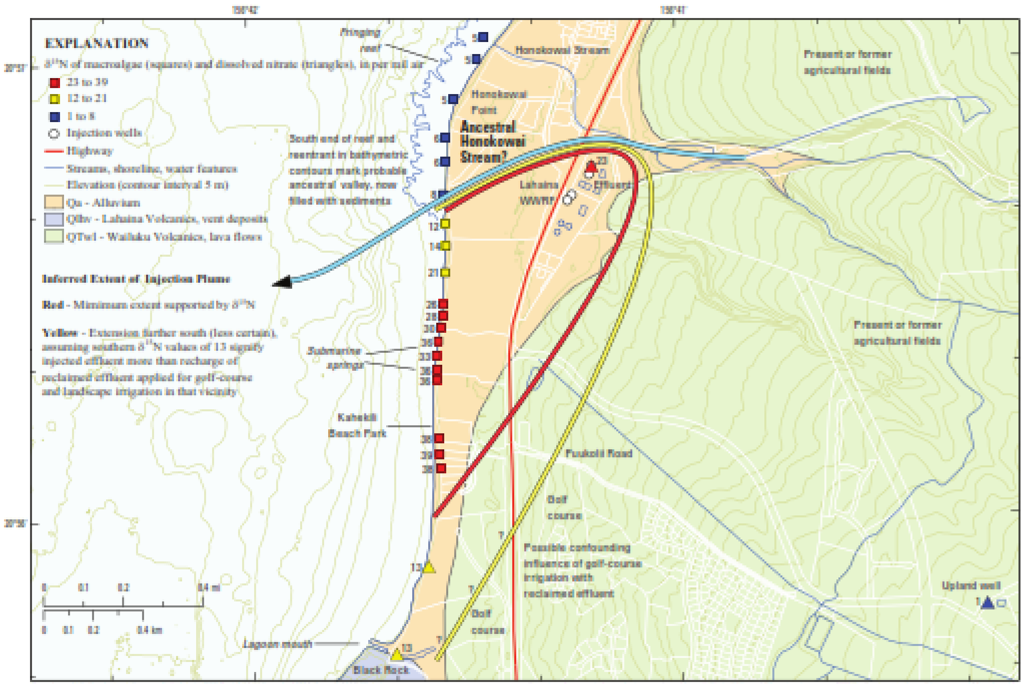


Exhibit 10 – Mathematical representation of flow fields from Wells 1&2 and 3&4. Assumes 5,000 m^3/d from each well pair, constant thickness aquifer and no mounding of injected flow.



Base from U.S. Geological Survey digital data (2004) at 1:24,000 scale, UTM Zone 4, NAD83 datum.

Street and property boundaries are from Hawaii State Office of Planning tax maps (2005). Geology is from Stearns and Macdonald (1942) and Sherrod and others (2007). Elevation contours were derived using gridded data from Taylor and others (2008).

Figure E3. Map showing the injection plume diverted south by a probable buried ancestral valley at Lahaina, Hawaii.

Exhibit 11- Injection plume from Hunt and Rosa (2006), Figure E3.

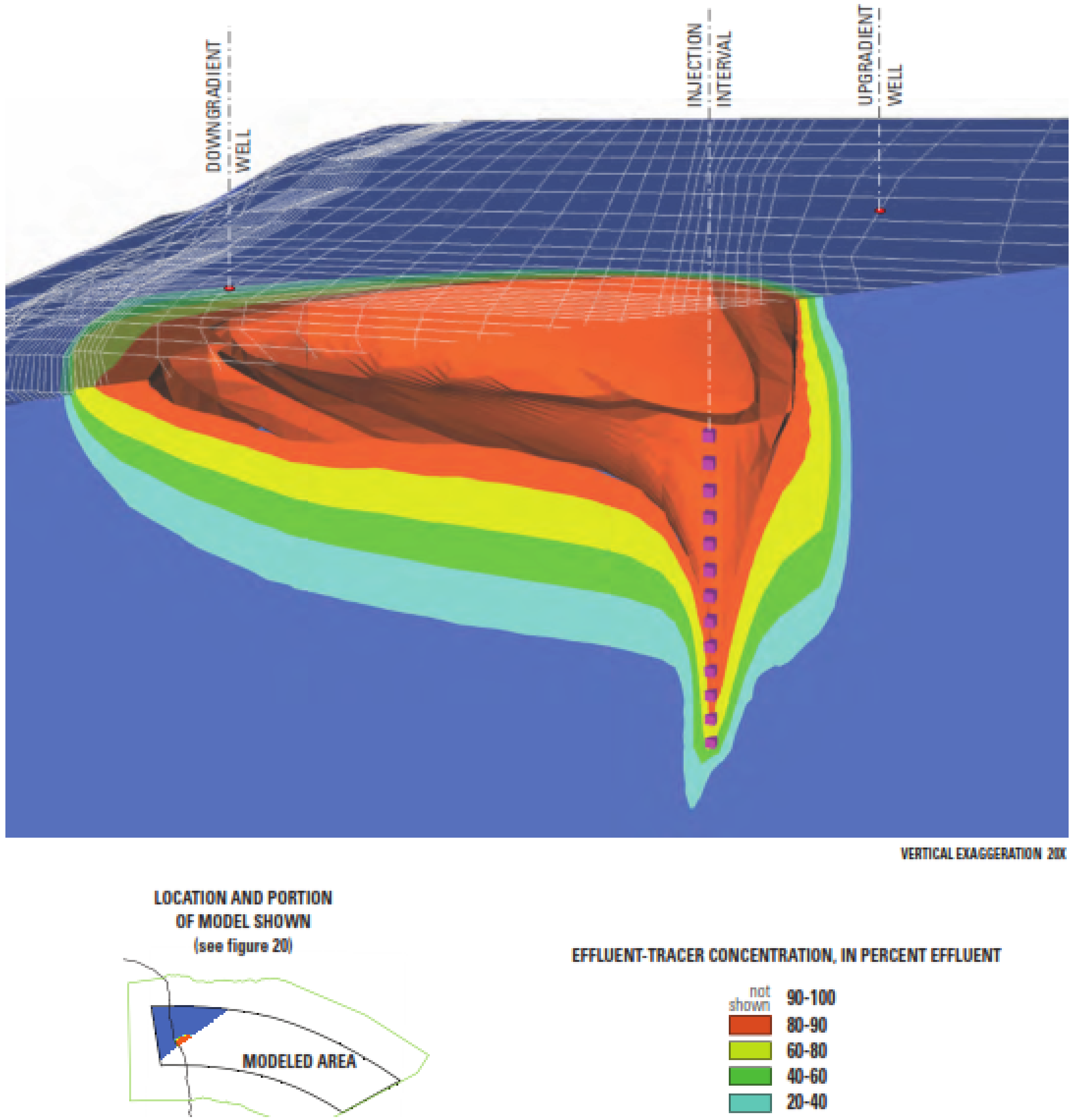


Exhibit 12 –Sectional view of simulation of injected effluent at Kihei (Hunt, 2007)

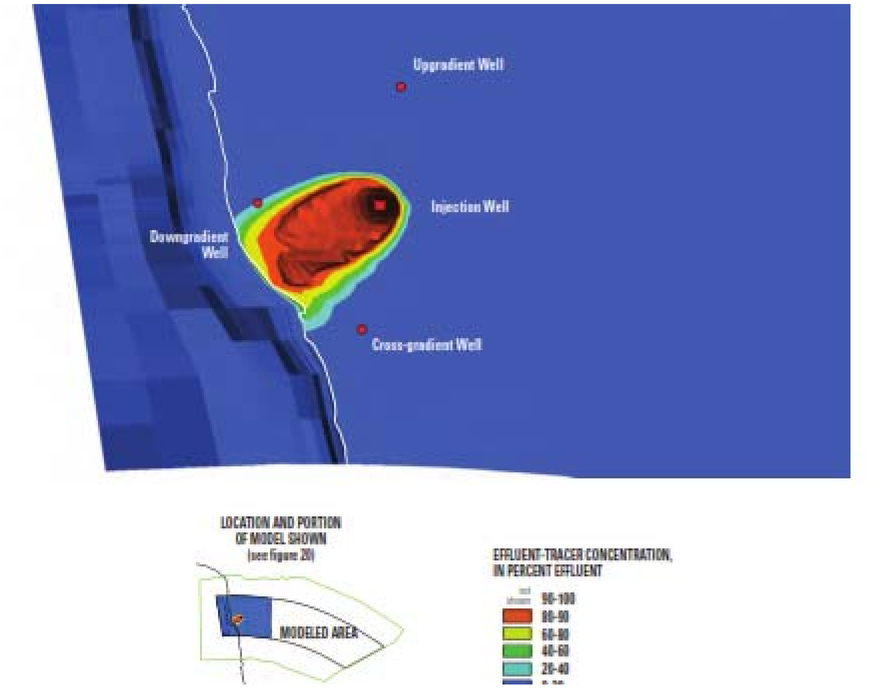
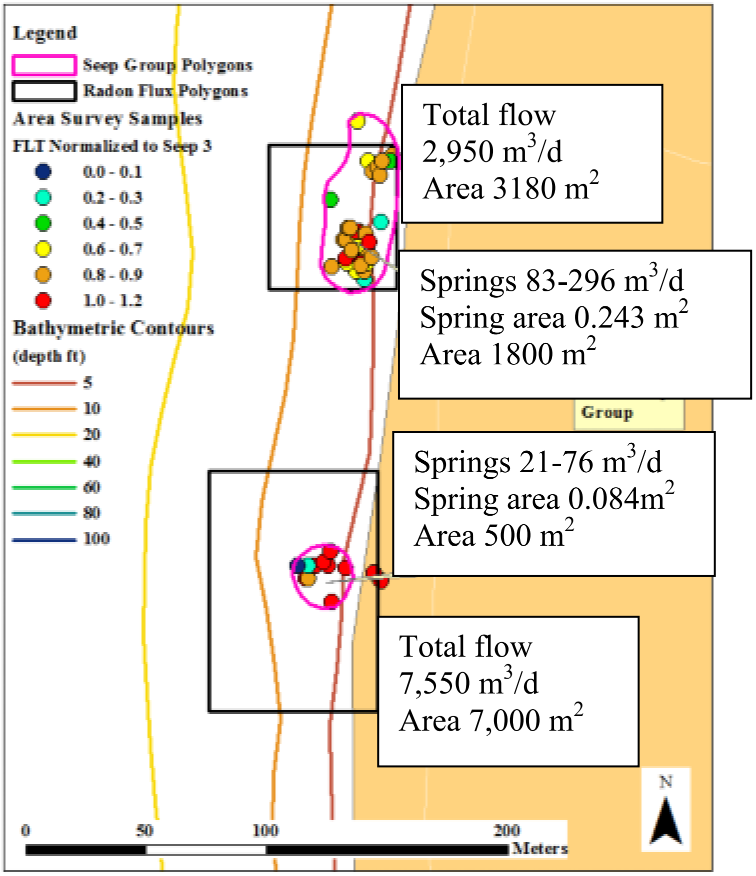


Exhibit 13 - Simulation (plan view) of injected effluent flow to coastline at Kihei (Hunt, 2007)



Total flow
2,950 m^3/d
Area 3180 m^2

Springs 83-296 m^3/d
Spring area 0.243 m^2
Area 1800 m^2

Springs 21-76 m^3/d
Spring area 0.084m^2
Area 500 m^2

Total flow
7,550 m^3/d
Area 7,000 m^2

Figure ES-4: The location of the flowing submarine springs showing an enveloping polygon for each seep group and the extent of the boxes used in the Radon flux calculations (compare with Figure ES-8).

Exhibit 14 – Flow estimates based on radon fluxes and direct measurement (*Report*, p. 3-4).

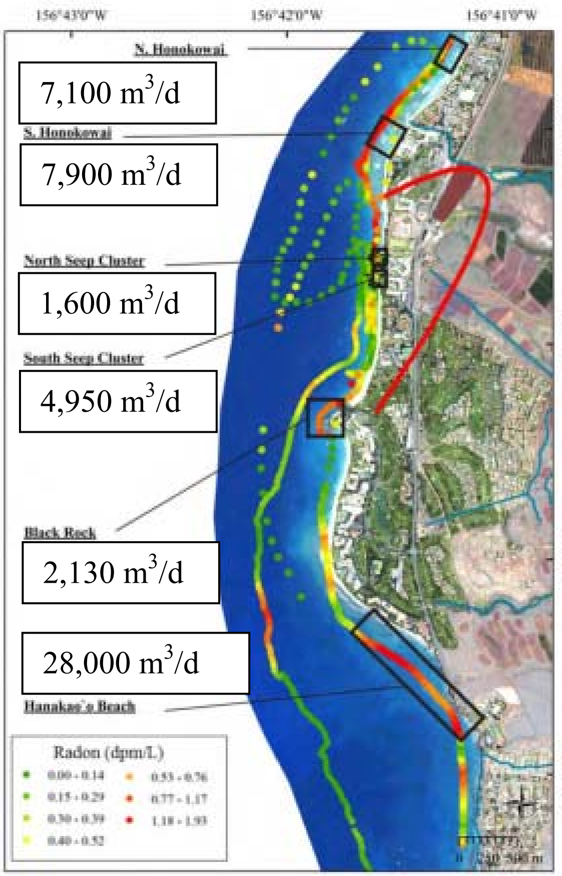


Figure ES-8: Radon activities measured during coastal surveys in June and September, 2011.
Sites with elevated surface radon activities are outlined with a black box. The lengths of the boxes are the approximate lengths of coastline that was within 100 dpm/m^3 of the mean radon concentration for each site and the widths are the distance of the radon survey from the coastline. The latter assumes that groundwater emanates at the coastline. Coastal groundwater fluxes were estimated from these areas. FLT plume boundary is also shown,

Exhibit 15 – Estimated freshwater flows (*Report*, Table 3-5a).

Exhibit 16 – Monitoring locations June 2011 (Figure 6-2, *Interim Report*).

Exhibit 17 – Monitoring locations September 2011 (Figure 6-3, *Interim Report*).

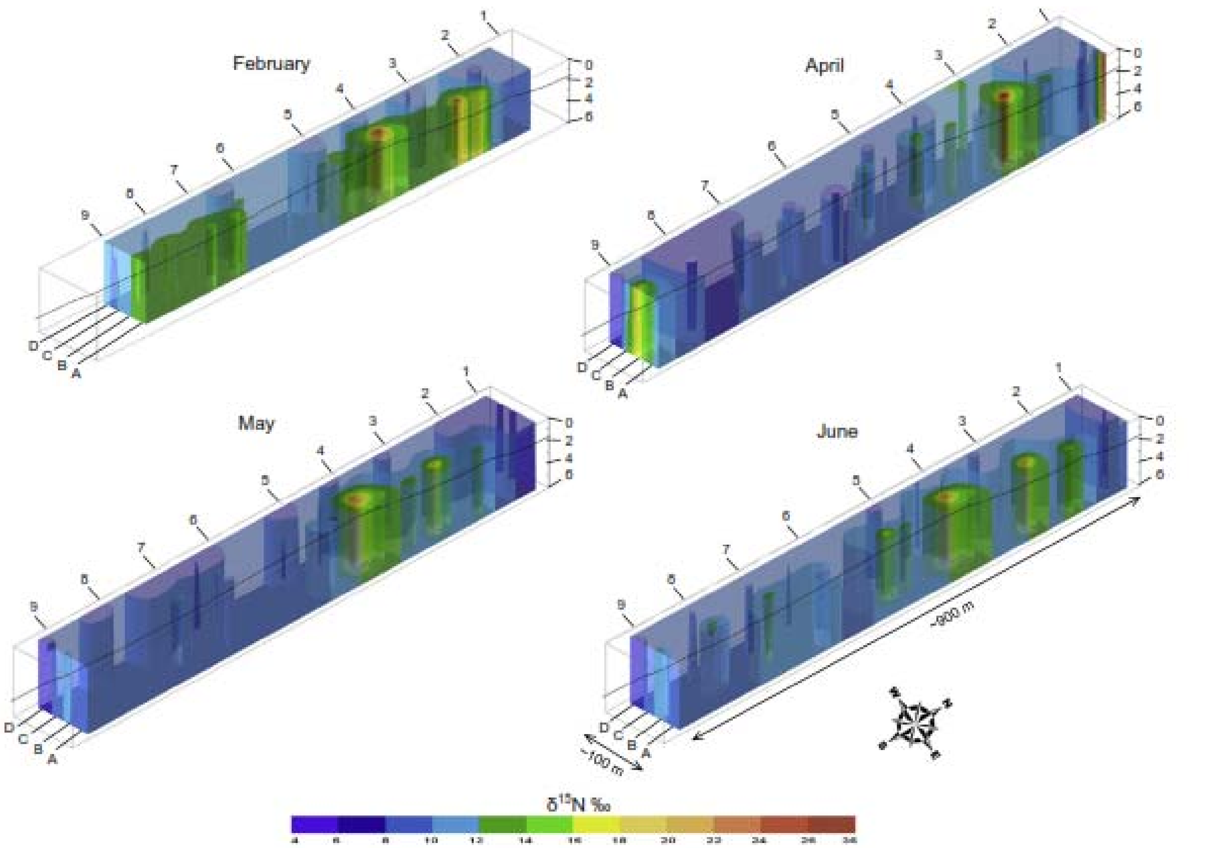


Fig. 4. Three-dimensional models of the wastewater effluent plume spanning the coral reef at Kahekili. The models were generated with EnviroInsite software from the $\delta^{15}N$ values of deployed algae in February, April, May and June 2010. Algal bioassay transects 1 through 9 are shown from north to south with deployment locations A–D from nearshore to offshore and the depth is shown from the surface (0 m) to the benthos (6 m).

Exhibit 18 – Distribution of $\delta^{15}N$ in nearshore waters at Kahekili (Dailer *et al*., 2012).

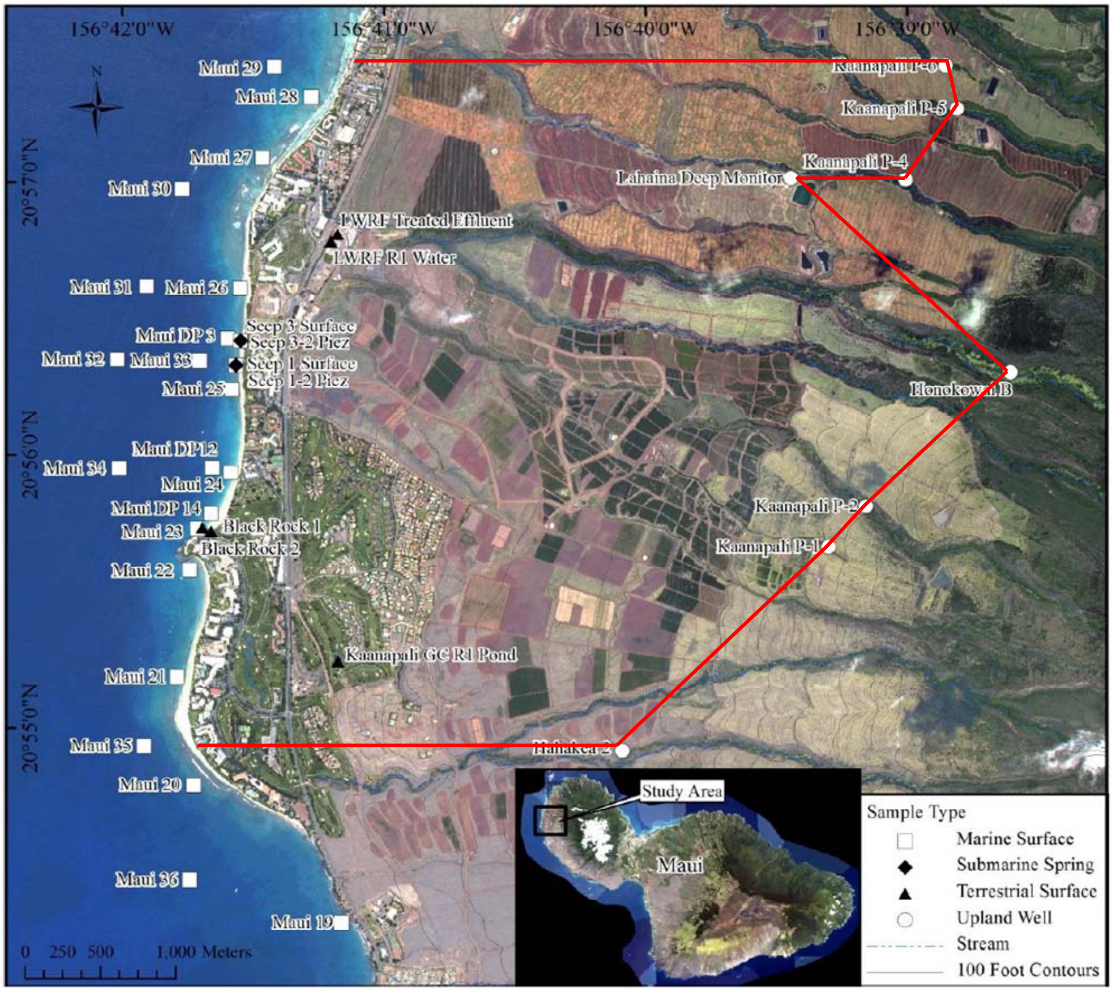


Figure 6-3: September, 2011 Sample Locations

Exhibit 19 - Area between shoreline and sampling locations for upland groundwater.

5. Witness qualifications

The witness has spent his entire professional career of 52 years devoted to research, teaching and engineering practice concerned with the analysis of the fate and transport of contaminants and tracers in the water environment, including rivers, lakes, coastal ocean and groundwaters. His *curriculum vitae* detailing his professional career, experience and publications is appended.

ERICSON JOHN LIST

Principal Consultant, Flow Science Incorporated
Principal Consultant, Environmental Defense Sciences
Professor *Emeritus* of Environmental Engineering Science,
California Institute of Technology

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PERSONAL

Citizenship:	U.S.A. Passport No. 215816027 Global Entry No. 983556301
Birthdate:	March 27, 1939
Place of Birth:	Whakatane, New Zealand
Home Address:	169 Broomfields Road, Whitford, New Zealand
Office Address:	48 S. Chester Ave., Suite 200, Pasadena, CA 91106

EDUCATION

1965 Ph.D.	California Institute of Technology (Applied Mechanics and Mathematics)
1962 M.E. (Civil Eng.)	University of Auckland, N.Z.
1962 B.Sc. (Mathematics)	University of Auckland, N.Z.
1961 B.E. (First Class)	University of Auckland, N.Z.

POSITIONS HELD

Dr. List is currently Principal Consultant of Flow Science Incorporated and Environmental Defense Sciences. He was Professor of Environmental Engineering Science at the California Institute of Technology from 1978-1997. He joined the faculty at Caltech in 1969 as an Assistant Professor, after spending three years as a lecturer and senior lecturer at the University of Auckland. For the period 1980-1985, he was Executive Officer for the Environmental Engineering Science Graduate Program at Caltech.

TEACHING EXPERIENCE

Fluid mechanics, turbulent diffusion, density-stratified flow, flow in porous media, introductory oceanography and meteorology, classical applied mathematics, singular perturbations, non-linear waves, mathematical programming and simulation, probability and statistics, solid mechanics, hydrologic transport processes, environmental fluid mechanics.

RESEARCH INTERESTS

Turbulent diffusion, buoyancy-modified flows, particle coagulation, coastal ocean and estuarine processes, reservoir modeling, transient flows, flow in porous media.

INSTITUTE AFFAIRS

Professor List served on sixteen different administrative and faculty committees, including a term as Vice-Chair of the Faculty (1979-81), and chair of the following Faculty Committees: Athletics and Physical Education (1975-79), Curriculum (1981-84), Membership and Bylaws (1979-81), and Nominating (1978-79). He served on the Jet Propulsion Laboratory Classified Research Oversight Committee for a period of six years.

EDITOR

Journal of Hydraulic Engineering, American Society of Civil Engineers, 1984-1989

MEMBERSHIP

Member, American Consulting Engineers Council
Honorary Life Member and Fellow of American Society of Civil Engineers
Chair, Hydrologic Transport and Dispersion Committee, 1983-84
Chair, Awards Committee, Hydraulics Division, 1994
Co-Chair, Third International Symposium on Stratified Flows, 1987
Chair, Engineering Excellence Committee, 1989

AWARDS AND RECOGNITION

Fulbright Scholar, 1962
National Science Foundation Award for Special Creativity, 1982
Who's Who in America (20 years)

REGISTRATION

Professional Civil Engineer No. 36791, State of California
Professional Civil Engineer No. 015627, State of Nevada

VISITING COMMITTEES

University of California, Irvine, School of Engineering, 1983, 1989
Stanford University, Palo Alto, Department of Civil Engineering, 1984

University of British Columbia, School of Engineering, 1990

BOARDS

Flow Science Incorporated, Pasadena, California (Chair) 1983-Present
City of Pasadena, Blue Ribbon Commission 1976-1978
Environmental Defense Sciences, Pasadena, California 1997-Present

CONSULTING

Professor List has consulted with more than 800 industrial organizations, consulting engineers and governmental agencies, including Southern California Edison, ChevronTexaco, ExxonMobil, Astra-Zeneca, Lockheed Martin, IBM, City and County of San Francisco, City of Los Angeles, City of Seattle, City of San Diego, City and County of Honolulu, Southern California Metropolitan Water District, Southern Nevada Water Authority, Los Angeles and Orange County Sanitation Districts. He has authored reports in the following areas of work: geothermal flows, river control modeling, power plant cooling systems, brine and wastewater diffusers, dredge spoil disposal, river dispersion, solar heat storage systems, reservoir destratification and mixing, well testing and failure, pulsation control and water hammer, pipeline failure, groundwater mass balance, ocean current and temperature analysis, acoustic resonance in piping systems, gas transfer, ocean dispersion, and biodegradation of organo-chlorines.

PUBLICATIONS

Professor List is co-author of the texts *Mixing in Inland and Coastal Waters* (Academic Press, 1979), *Turbulent Buoyant Jets and Plumes* (Pergamon Press, 1983), and the award-winning *Handbook of Groundwater Development* (Wiley, 1990). In addition, he is the author or co-author of the following refereed publications:

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6. Litigation experience of the witness since 2010.

Date	*Case*	*Client*	*Attorney*	*Role/Outcome*
2014 – ongoing	West Valley Water District et al v. Fontana Water Company	Fontana Water Company	Fred Fudacz, Nossaman LLP Los Angeles, CA	Expert witness on groundwater supply. Ongoing.
2012	NZ Dept of Labor v. WaterCare	WaterCare, Auckland NZ	John Billington, QC (Auckland, NZ)	Determine cause of pipeline explosion that resulted in death and injury. Settlement
2012	Orange County Water District Well Contamination (Newport, CA)	The Irvine Company Irvine, CA	Elizabeth Weaver Fulbright & Jaworski (Los Angeles, CA)	Develop scientific arguments for defense against claims of well contamination. Settlement.
2011	Los Angeles Harbor Superfund Site	Montrose Chemical Corporation	Paul Singarella Latham & Watkins (Newport, CA)	Providing scientific expertise. Settlement
2009 – 2010	San Francisco Water Treatment Plant Earthquake Failure, CA	City and County of San Francisco Public Utilities	Louise Simpson City Attorney's office	Investigate and determine cause of failure. Settlement
Sep 2009 – April 2010	McConnell Dowell v. AECOM, New Zealand	McConnell Dowell	John McKay Chapman Tripp (Auckland, NZ)	Advise on hydraulic design of Rosedale Outfall. Settlement.
2007- ongoing	Rialto Colton Well Contamination, Fontana, CA	San Gabriel Valley Water Company	Fred Fudacz Nossaman, Guthner, Knox, Elliott (Los Angeles, CA)	Investigate source and spread of perchlorate contamination. Ongoing
2006 – ongoing	Antelope Valley Groundwater Adjudication, CA	Tejon Ranch Corporation	William Kuhs Kuhs Parker & Hughes (Lebec, CA)	Develop scientific basis for client's claim to share of groundwater. Ongoing trial.

Date	*Case*	*Client*	*Attorney*	*Role/Outcome*
2006-ongoing	Halls Brook Holding Pond, Industri-Plex Site, Woburn, MA	AstraZeneca (Stauffer Management Company)	Paul Galvani Ropes & Gray (Boston, MA)	Developed scientific arguments for case defense regarding arsenic and ammonia contamination. Settlement negotiations with USEPA ongoing.
2005-2012	San Diego Harbor Superfund Site, CA	ChevronTexaco	Christopher McNevin Pillsbury Winthrop Shaw Pittman (Houston, TX)	Developed scientific arguments for defense against claims of PAH contamination. ChevronTexaco released from case.

7. Witness compensation

Witness has been retained by County of Maui to provide expert witness services and testimony. Under the terms of that agreement witness's company will be paid $314/hour for witness labor, which is the company's standard rate for such services. The witness will be paid $2000/day for trial testimony and reimbursed expenses at cost.