Problem and Research Objectives

Faga’alu Valley on Tutuila Island, American Samoa, has been designated as a priority watershed management area by the NOAA Coral Reef Conservation Program. While Faga’alu’s surface water is on the AS EPA 3 03(d) list of impaired waters (CRCP 2013), at present, there is no information available regarding groundwater derived pollution in the valley. In its coral rich bay, near-shore ecosystem health is threatened by terrigenous sediments, nutrients, and other pollutants that are likely transported via stream and groundwater discharge (CWP 2012). The American Samoa Environmental Protection Agency’s (ASEPA) coral reef monitoring program has determined that Faga’alu’s benthic ecosystem is one of the most impacted on the island (Houk 2005).

This study strives to evaluate surface-water-groundwater interactions within Faga’alu Stream and to quantify groundwater to stream flux and submarine groundwater discharge rates into Faga’alu Bay. Since groundwater has been shown to be a potentially significant source of nutrients and other anthropogenic contaminants in similar environments (Johannes and Hearn 1985, Dulaiova et al. 2006, Burnett et al. 2007) a more complete understanding of groundwater derived contributions are needed to assess the degree of anthropogenic impact and nutrient loading to the coastal ecosystem. By examining multiple geochemical parameters and integrating ground/stream water flux rates with nutrient and isotopic tracer data we are currently working to quantify contaminant loading from different sources, and assess the degree of human impact on this fragile ecosystem.

Methodology

In summer 2014 a field campaign on Tutuila was completed. During this time samples and direct measurements were taken from the accessible length of Faga’alu Stream, from all observable coastal groundwater discharge sites, and throughout Faga’alu Bay.

Stream Sampling and Gauging Methods

Faga’alu Stream was sampled and/or gauged at nine locations throughout its lower reaches (Figure 1). Streamflow was measured using a Price-type Pygmy Current Meter and the velocity-area-method (Turnipseed and Sauer 2010) was used to calculate discharge. All stream samples were taken at baseflow conditions during a single 24 hour period. Samples were collected from the middle of the water column and filtered with a 0.45 µm hydrophilic polyethersulfone capsule filter. Temperature, salinity, pH and dissolved oxygen were measured in situ with a YSI multiparameter sonde (6600V2-4 model). Samples were collected in triple-rinsed acid cleaned 60 ml HDPE bottles and were immediately chilled for transport to storage facilities. Grab samples were analyzed the same day for dissolved radon gas concentrations and chilled samples were analyzed at University of Hawaii laboratories for inorganic nutrients, total dissolved C, N and P, major ions, δD & δD18O of water, δ15N & δD18O of NO3− and δ13C of inorganic carbon.

Coastal Groundwater Discharge Sampling Methods

A number of freshwater springs were identified along the coast at Faga’alu Bay. These were sampled and analyzed using the aforementioned stream sampling methods. Also three
Stream gauging and sampling was performed in the lower reach of Faga’alu Stream. This reach encompassed the majority of human development within the valley. Coastal groundwater discharge locations were selected for installation of two meter long PVC piezometers which were placed roughly 0.3 m below the water table. Piezometers were outfitted with conductivity, temperature, and depth (CTD) loggers for one week and water samples were taken during both high and low tide from one piezometer. There is a single production well in Faga’alu Valley and water samples from this well were also collected to be used as potential groundwater endmembers.

Coastal Water Sampling Methods

A coastal survey through the inner bay was conducted via boat during a low tide cycle. The craft was instrumented with a continuously logging YSI multiparameter sonde (6600V2-2 model) and a continuously logging dissolved radon gas detector (Durrage Rad7). In addition, depth profiles were conducted with a CTD logger every 5 minutes during the survey and coastal water samples were collected roughly every 10 minutes during the survey. Water samples were analyzed using the same procedures as the stream samples. Survey data is currently being analyzed with methods from Burnett and Dulaiova (2003) with updated gas-liquid equilibrium constraints based on equations in Schubert et al. (2012).

Time-series Deployment Methods

To quantify tidal variations in SGD a continuous stream of coastal water from a single location was pumped through on-shore instrumentation which included a YSI multiparameter sonde (6600V2-2 model) and a continuously logging dissolved radon gas detector. These
Note: The stream mouth is located 1,250 m from Faga’alu quarry.

Figure 2. Nitrogen dynamics along Faga’alu Stream as it travels through the developed part of the watershed.

Instruments recorded variations in salinity and radon gas concentrations over a 48-hour period consisting of multiple tidal cycles. Water samples were periodically taken from the apparatus and analyzed as mentioned above. Data is currently being analyzed.

Principal Findings and Significance

Stream Water Quality and Nutrient Flux

Direct measurements of dissolved radon in Faga’alu Stream during baseflow conditions indicate a close connection between stream water and groundwater. The stream appears to be continuously fed with groundwater throughout its entire length, meaning dissolved constituents originating from the aquifer are discharged to the bay through not only coastal springs, but through the stream as well. Although the upper reaches of Faga’alu Stream are most likely gaining water via springs and seepage, gauging data indicates the lower reach is losing water to the aquifer over much of its length as it travels over the alluvial valley fill. Once the stream reaches an elevation nearing sea level, an increase in flow and a nearly four-fold increase in dissolved radon concentrations suggests a contribution to the stream from the basal groundwater lens. Streamflow throughout this lower reach is supplemented by small spring-fed tributaries which also bring radon and anthropogenic nutrients into the stream. Stream samples show an increasing trend of total nitrogen concentrations as well as $\delta^{15}$N values as the stream travels through developed areas to the bay (Figure 2). This indicates inputs of nitrogen to the
stream are most likely derived from human or animal waste products (Kendall and McDonnell 1998).

Coastal Water Quality and Groundwater Influence

Preliminary results based on measurement of coastal radon inventory, indicate a significant amount of groundwater is discharging into and influencing the chemistry of surface waters in Faga’alu Bay (Figure 3). In these coastal waters, levels of inorganic nitrogen also appear to be significantly higher than in ambient ocean water. Our study suggests that during low-flow conditions baseflow, as opposed to surface water contributions, acts as the primary source of nutrients in the stream. At present our analysis is continuing to focus on the delineation between the effects of stream derived inputs and those from groundwater, by looking at salinity measurements and radon concentrations. This coastal survey data and a recent sediment modeling study (Messina 2012) both indicate the presence of a persistent clockwise moving current in the bay that transports sediment, surface water, and any groundwater derived constituents from the south to the north side of the bay. Nutrient concentrations in coastal surface waters are roughly twice as high in the waters of the north side of the bay (Figure 3).
Coastal Spring and Groundwater Nutrients

The four discrete coastal springs that were found were sampled multiple times over varying tidal conditions. The nearshore groundwater environment shows geochemical complexity and nutrient results vary widely depending on the timing of sampling (based on tidal stage) and the observed redox conditions in the water at the time. Although the speciation of nitrogen in coastal springs was highly dependent on localized redox conditions, the total nitrogen concentrations discharged to the bay from coastal springs were roughly 3–4 times higher than those observed in stream and coastal bay waters (Figure 4). Though we have yet to quantify groundwater flux rates into the bay, the low levels of observed nitrogen in stream waters and the only slightly lower concentrations of nitrogen found in coastal waters leads us to believe that groundwater nutrients are a significant controlling factor for the geochemistry of the bay. Further analysis will focus on understanding the unique aquifer chemistry and biogeochemical reactions that apply to the valley’s groundwater.

Coastal spring and inland groundwater samples from Faga’alu are unique when compared to groundwater from other parts of the island. The valley has historically been subject to a higher degree of anthropogenic modification due to the presence of U.S. Navy operations. Many groundwater samples have unusually low dissolved oxygen concentrations, potentially indicating a buried source of organic carbon that may be related to construction fill historically used to create developable land in the valley.
Future Work

Objectives still to be completed include:

- Quantification of groundwater flux rates and plume geometry using methods similar to those in Peterson et al. (2009).
- Partitioning of stream water vs. groundwater as transport mechanisms for nutrients and other anthropogenic contaminants.
- Developing a better understanding of the biogeochemical reactions, (e.g., denitrification, sulfate reduction, etc.) which control groundwater chemistry and speciation of nutrients in the near shore environment.

Publications Cited in Synopsis


Turnipseed, D.P., and V.B. Sauer, 2010, “Discharge measurements at gaging stations,”
U.S. Geological Survey techniques and methods, Book 3, Chapter AS, USGS, Reston, VA.