In addition to monitoring coral health, effective coral reef conservation requires a more integrated understanding of sediment dynamics linking key sources in the watershed to the spatial distribution of sediment accumulation on the reef (Downs et al., 2005; Klein et al., 2012; Risk, 2014). Coral reef managers are interested in establishing baselines for objective metrics of intervention success like reduced sediment loading to bays or reduced sediment accumulation on coral reefs (Kroon, 2012), and these metrics require simple yet effective methods to quantify sediment yield from key areas, characterize water circulation over the reef, and measure sediment accumulation on corals.

This research is expected to identify and quantify key sources of sediment and nutrient loading to Faga’alu Bay, monitor sediment and nutrient loading from natural and disturbed areas in Nu’uuli to compare to Faga’alu, and monitor sedimentation on the coral reef in Faga’alu Bay. Novel datasets collected in the field will be used to develop and parameterize simple models of land-based coral sedimentation to focus management efforts and develop objective metrics of management effectiveness. The methodology developed is intended for environmental management with few resources in data-scarce, tropical watersheds.

Significant research has been conducted on sedimentation dynamics in coral reefs in Hawaii (Presto et al., 2006; Storlazzi et al., 2009), Great Barrier Reef (Fabricius et al., 2012; Wolanski et al., 2005), Guam (Wolanski et al., 2005), Virgin Islands (Gray et al., 2012), Puerto Rico (Ryan, et al., 2008), Okinawa (West and van Woesik, 2001), Pohnpei (Victor et al., 2006) and New Caledonia (Ouillon et al., 2010). However, few

It is hypothesized that human disturbance in Faga’alu, mainly by open-pit aggregate mining, has significantly increased terrigenous sediment loading to the bay above the undisturbed baseline. This will be tested by 1) comparing Q-SSC relationships measured below the undisturbed and disturbed subwatersheds, 2) average Disturbance Ratio and percent contribution to total sediment load, and 3) comparing SSYEV rating curves from the undisturbed and disturbed subwatersheds. These analyses will provide novel data on SSY under natural and human-disturbed conditions from small, mountainous watersheds on steep, volcanic Pacific Islands.

Flow velocities in wave-driven environments exhibit a pattern of rapid, cross-shore flow near the reef crest that slows and turns along-shore towards a deep channel where water returns seaward, limiting cross-shore exchange of sediment from the reef flat to the forereef (Hench et al., 2008; Lowe et al., 2009; Wyatt et al., 2010). In wind-driven systems, flows are more predominantly in the direction of the wind with possible cross-shore water and sediment exchange from the reef flat to the forereef (Storlazzi et al., 2004), distributing sediment impacts from the muddy reef flat to the forereef (Presto et al., 2006). Observations on the wind-dominated reef flat in Molokai, Hawaii, showed current speeds were faster where the reef is deeper and narrower (Storlazzi et al., 2006c) but field observations at the wave-dominated proposed study site suggest the opposite; current speeds are rapid over the shallow reef crest, slowing significantly when reaching deeper pools in the reef and the main channel that bisects the reef.

Hydrodynamic conditions control sediment dynamics both by flushing suspended sediment away from corals before deposition, and resuspending and removing previously deposited sediment (Hoitink and Hoekstra, 2003; Presto et al., 2006). In reef environments where shallow reef crests limit the propagation of incoming surface wave energy, wave action alone may be insufficient to resuspend and disperse sediment, but in combination with wave- or wind-driven currents, orbital velocities may reach critical shear stress for sediment resuspension and dispersal (Ogston et al., 2004).

**Sediment plume dynamics in Faga’alu**

Following large or intense storm events, suspended sediment is discharged into Faga’alu Bay and advected seaward over the reef by momentum, in a thin surface layer of high suspended sediment concentration (SSC)(>500mg/L)(Figure 3). This sediment-rich layer attenuates photosynthetically active radiation (PAR; (Piniak and Storlazzi, 2008)) and transports fine-grain sediment over the reef where it can settle out of the water column and onto coral organisms. Although the hypopycnal surface plume is able to move counter to prevailing currents (upcurrent) by sliding over denser seawater, as sediment particles settle they are entrained in the prevailing current and transported accordingly (Wolanski et al., 2003). As flow velocities increase, residence time of the plume over the reef flat decreases, limiting time for small particles to settle out of the water column and controlling the sediment accumulation rate, even for the same concentration and magnitude of different plumes. In general, field observations (Figure 3) suggest the sediment plume following rain events is deflected north, limiting sedimentation on the southern reef, and focusing sediment stress on the northern reef.

GPS-tracked drifters have traditionally been used to characterize circulation in the deep or coastal ocean (Davis, 1991; Warrick et al., 2007), but less expensive, smaller GPS technology has recently made it possible to deploy many (n≥10) small drifters in nearshore environments to map flow patterns at finer spatiotemporal resolution (Austin and Atkinson, 2004; Johnson et al., 2003; MacMahan et al., 2010; Storlazzi et al., 2006a).

Lagrangian current velocity data from five GPS-logging drifters was collected over 30 deployments during two months, coinciding with Eulerian current velocity data from three Acoustic Doppler Current Profilers (ADCP) collected for one week. Drifter deployments typically lasted 1-2 hours.

It is hypothesized that under low wave conditions, mean flow directions are more variable and mean flow speeds are lower. Under high wave conditions, mean flow patterns are more coherent in a single direction at a given point and mean flow speeds are greater. Flow patterns are less variable near the reef crest, and more variable on the reef flat, especially the northern reef flat. These hypotheses will be tested by variance ellipses calculated from spatially binned ADCP and drifter data, categorized by end-member forcing condition.

It is hypothesized that residence time of water over the northern reef will be longer than over the southern reef, despite the much smaller area of the northern reef, because wave exposure and resulting flow speeds are lower. This hypothesis will be tested by averaging residence time in each 10m x 10m bin over the north and south reefs under end-member conditions, and comparing their relationships with wave-, wind-, and tide-forcing.

Coral stress and mortality resulting from sediment in the water column and sediment deposition is a complex process depending on hydrodynamics, sediment biogeochemistry, coral morphology, and coral physiology (Fabricius, 2005; Weber et al., 2012), making it difficult to quantify coral stress caused by sediment using biological monitoring strategies alone.

This research focuses on understanding how the temporal and spatial distribution of sediment deposition on the reef is controlled by terrigenous sediment loading and oceanic conditions. Future research can relate the measured sediment deposition to coral health.

Depending on the interacting hydrodynamic processes on the reef, increased terrigenous sediment supply to an embayment can increase sediment deposition on corals (Draut et al., 2009), or have no effect (Hoitink and Hoekstra, 2003).

Wave energy from remotely generated surface gravity waves or local wind-driven waves is typically limited on shallow reef flats, but can cause high orbital velocities or combine with current velocities (Ogston et al., 2004) to resuspend and flush previously deposited sediment.

Many studies have measured sediment deposition in coral reefs but few have developed an integrated understanding of the temporal interaction of flood-supplied sediment, water circulation patterns, and the resulting deposition on corals. The studies that have integrated terrestrial and marine sediment dynamics were limited by a small number of flood events in a drier area (Ogston et al., 2004), shorter sampling times (Wolanski et al., 2005, 2003), or focused on larger areas with more complex geochemistry and forcing (Draut et al., 2009; Storlazzi et al., 2009). Other studies have focused on only the tropical wet season when deposition is highest, and neglected investigating the important dynamics of potential sediment removal and flushing during the dry season (Muzuka et al., 2010; Victor et al., 2006). This research complements these other studies by focusing on high spatial density sampling of a small area over a full year to investigate temporal and spatial distributions of sediment accumulation.

Much research has focused on correlating coral health metrics like percent coral cover with sediment metrics like turbidity in the water column (Fabricius et al., 2012) or sediment accumulation on the reef or in traps (measured as mass per area per time)(Muzuka et al., 2010; Presto et al., 2006).

In the study location (American Samoa), the wet season (Nov-Apr) is associated with increased sediment loading from the watershed, light or absent trade winds and relatively low wave heights, while the dry season (April-Oct) has decreased sediment loading, stronger trade winds and larger swell heights (Figure 9). Current measurements and field observations suggest that there is a consistent hydrodynamic pattern, where ocean water is pumped over the southern reef crest by breaking waves, driving clockwise flow over the reef (Figure 4) that protects the southern reef from the sediment plume, and deflects the sediment plume over the northern reef.

This model is used to test hypotheses about temporal and spatial distributions of sediment accumulation, and provide a baseline for measuring the effectiveness of sediment mitigation activities in the watershed.

**Hypothesized interactions of watershed and hydrodynamic processes**

Hypothesis 3.1: Terrigenous sediment deposition will be highest, and marine-derived deposition lowest in the wet season, when rainfall events and watershed sediment inputs co-occur with light offshore winds and quiescent ocean conditions. In the dry season, stronger, onshore trade winds and higher average swell heights will decrease rates of terrigenous sediment deposition and shorten residence times, but will increase resuspension and deposition of marine-derived carbonate sediment compared to the wet season.

Hypothesis 3.2: The spatial distribution of sediment accumulation will be controlled by the velocity of water circulation over the reef flat, and the distance from the point of sediment discharge (stream mouth).

Hypothesis 3.3. The relative importance of watershed and hydrodynamic controls on the temporal variability of sediment accumulation will differ by location in the bay, with more hydrodynamic control at the sites further from the stream that are not exposed to watershed inputs, and greater importance of watershed inputs in the parts of the reef closer to the stream.

These hypotheses will be tested with measurements of sediment loading from the watershed, accumulation and composition of sediment in traps on the reef, and oceanic and meteorological conditions. The impact of watershed inputs and water circulation will be assessed with statistically-based mathematical models.

Approaches to measuring sediment impacts on coral health have included monitoring SSC or T in the water column (Wolanski et al., 2003) but SSC can be increased by resuspension of nearby sediment and/or advection from another area, and does not necessarily cause sediment deposition. Geochemical methods (Takesue et al., 2009), sometimes in conjunction with coral skeleton analysis (Grove et al., 2010; Perry et al., 2012), have been used to infer sediment deposition over decadal and century time scales (Ryan et al., 2008) but can be complicated by subsequent sediment reworking and these time scales are ill-suited to the time scales of coral mortality and effective environmental management.

Since tube traps slow the water column and prevent resuspension, they can effectively trap sediment that would have been advected through the area without being deposited (Storlazzi et al., 2011).

### Sediment composition and particle size

Sediment samples collected in tubes and SedPods are wet sieved to separate the rinse salt from the sample and assess particle size. The samples are dried and weighed to determine bulk sediment accumulation before being shipped to SDSU to characterize the geochemical composition (percent terrigenous, carbonate and organic) using Loss on Ignition (LOI) method (Heiri et al., 2001; Santisteban et al., 2004). The LOI method uses a muffler furnace that can sustain 950 C for several hours to combust and remove organic, then carbonate material, leaving only terrigenous residue. All carbonate sediment is assumed to be reef derived, all non-carbonate is assumed to be terrigenous (Ryan et al., 2008). See QAPP 3.5. The particle size distribution and geochemical composition of sediment collected in traps may differ from sediment that accumulates on the reef, so sediments in the immediate area of the trap are sampled. See QAPP 2.2.11.5.

Current conservation models typically use the distance from the river mouth or other point source to assess pollution risk to coral reefs (Doheny et al., 2013; Klein et al., 2012), but wave and wind-driven flow over the reef can deflect suspended sediment away from corals (Hoitink and Hoekstra, 2003) or focus impacts on small areas of reef (Presto et al., 2006).

Drifter designs typically involve the use of a suspended drogue (Johnson et al., 2003; Ouillon et al., 2010) or a finned tube (MacMahan et al., 2009) to extend into and anchor the drifter in the water column. However, due to the shallow conditions experienced on reef flats a novel drifter design was needed. Drifters for shallow coral reef environments need to be shallow enough to avoid interaction with corals, deep enough to not be affected by the surface movements, extend high enough to be visible but not high enough to be affected by winds, and finally, rugged enough to sustain the impact of a breaking wave onto corals in the event it is entrained in the surf zone.

Five drifters were designed and constructed on-island, from PVC tubing and plastic sheeting, with a small waterproof housing for the GPS recorder (HOLUX M1000), and a float collar to maintain upright orientation