Supplementary material for manuscript:

# Submarine groundwater discharge and stream baseflow sustain pesticide and nutrient fluxes in Faga'alu Bay, American Samoa

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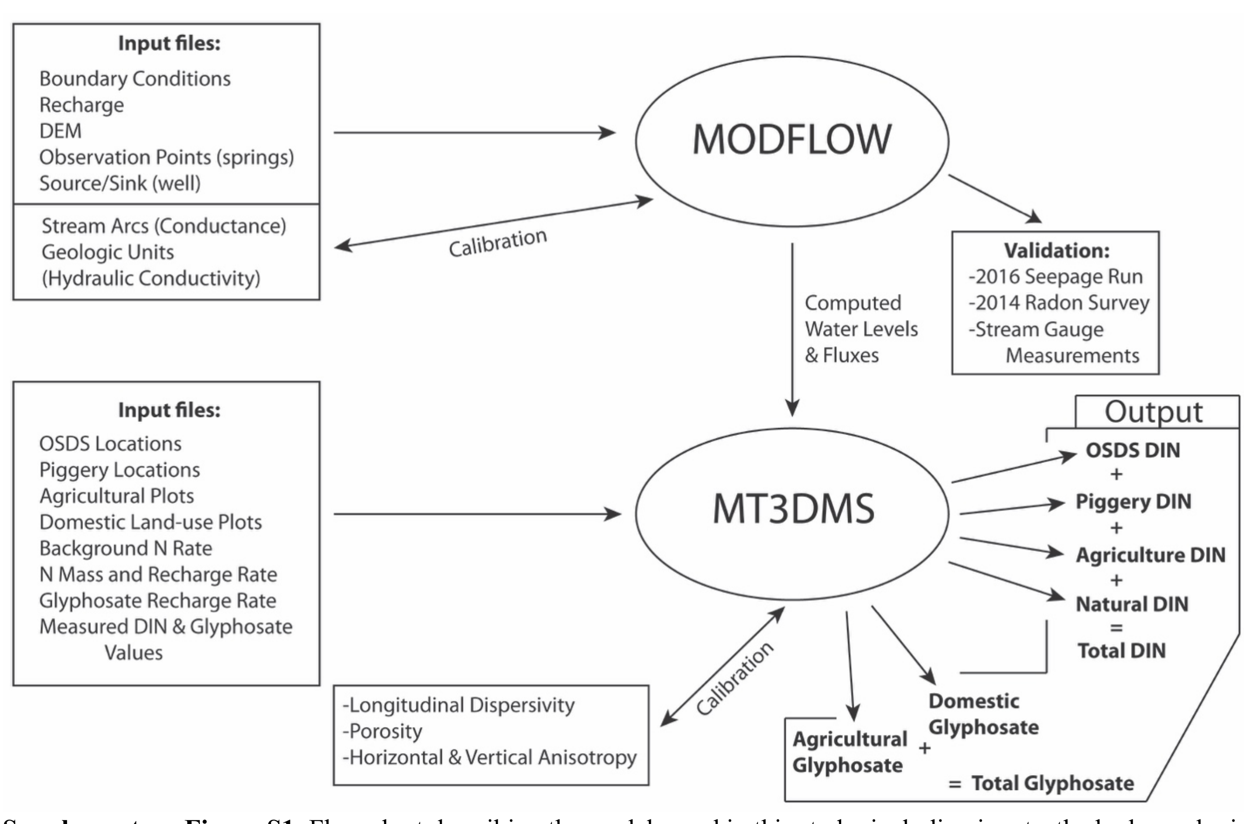
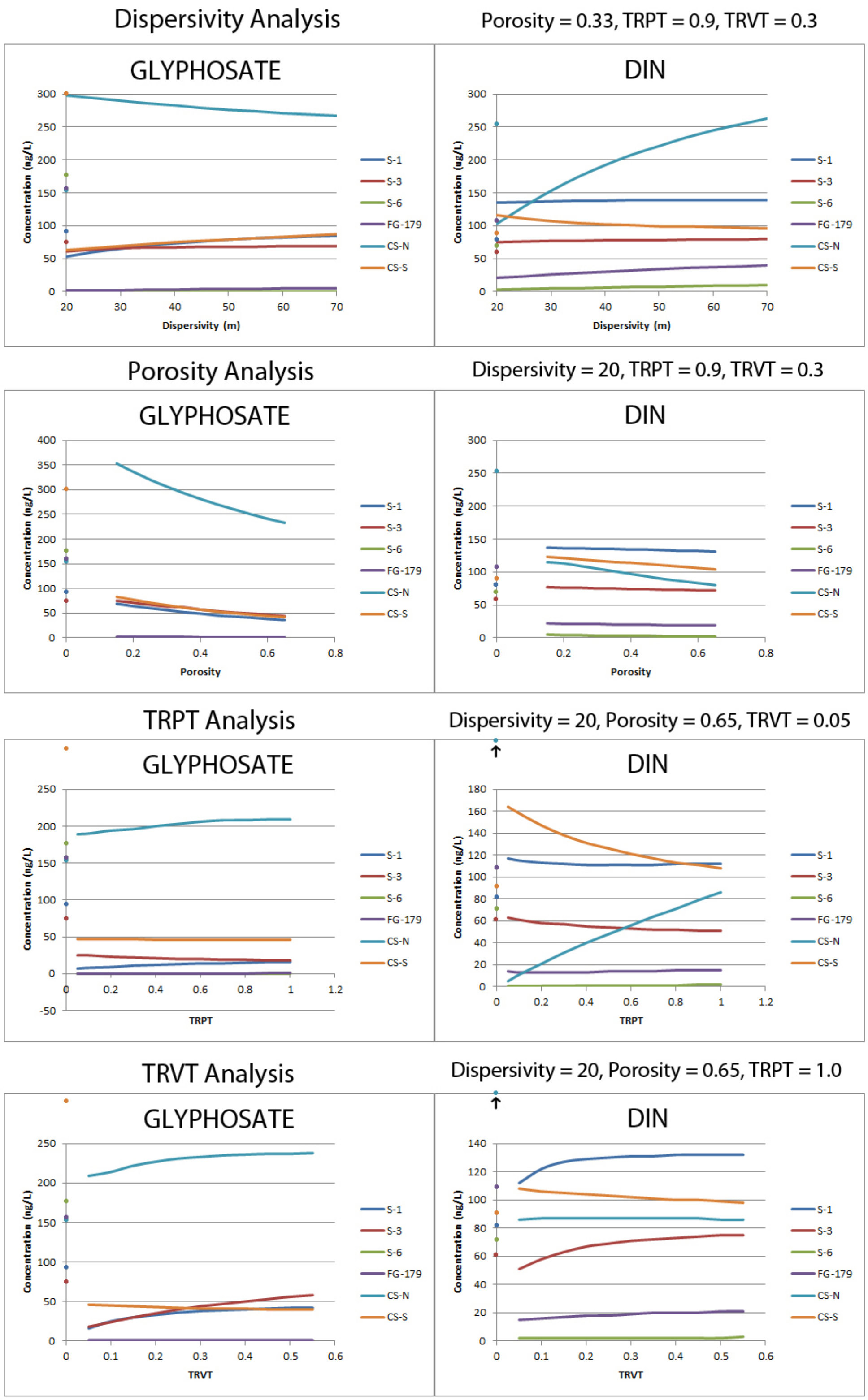
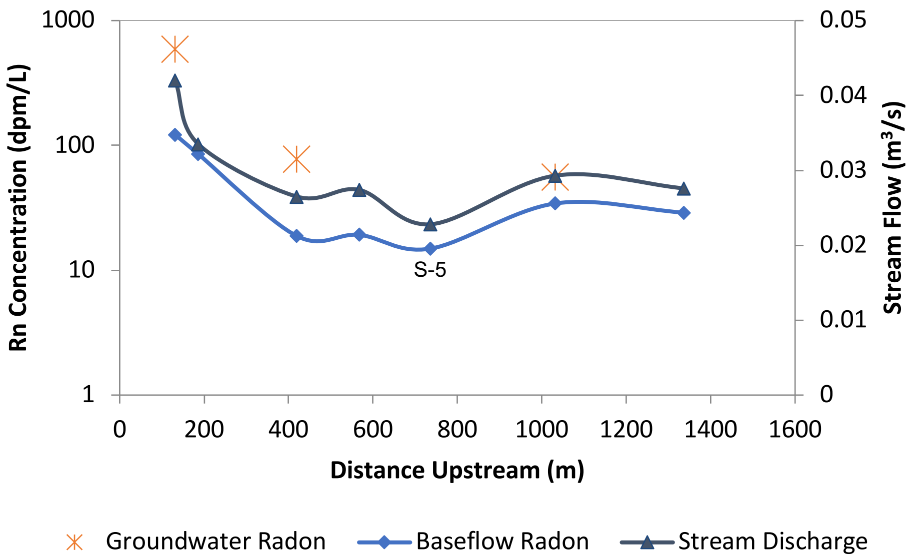



**Supplementary Figure S1**: Flow chart describing the models used in this study, including inputs, the hydrogeological model (MODFLOW), the transport model (MT3DMS), and model outputs along with validation against field observation collected in this study as well as against a 2014 SGD coastal Rn survey by Shuler et al. 2019.




**Supplementary Figure S2:** A sensitivity analysis was run for four parameters within the transport model. Observed concentrations at the sampling sites are marked with colored points on the y-axis matching the color of the modeled lines representing results of the different scenarios.




**Supplementary Figure S3:** Measured stream discharge and $^{222}$Rn concentrations observed in Faga'alu Stream at 6 stations showing gaining sections upstream of 1000 m from the coastline and near the coastline which is at 0 m. Groundwater radon concentration extracted from stream bank at 3 locations are indicated by crosses. Station S-5 was selected as a boundary between the upper and lower reaches of the Faga`alu Stream, which was used in determining high level and basal aquifer baseflow fluxes.

**Supplementary Table S1:** Salinity measurements were obtained from YSI Multiparameter sonde. Radon-222 measurements in dpm/L (decays per minute per liter) from all groundwater and surface sites were measured by a radon-in-water Rad-H2O instrument ( Durridge Rad7 accessory).

| **GW site** | **Salinity** | **$^{222}$Rn (dpm/L)** | **Surface site** | **Salinity** | **$^{222}$Rn (dpm/L)** |
|---|---|---|---|---|---|
| S-1 | 0.19 | 590 | S-1 | 0.14 | 120 |
| S-3 | 0.09 | 80 | S-2 | 0.10 | 90 |
| S-6 | 0.08 | 60 | S-3 | 0.09 | 20 |
| FG-179 | 0.12 | 330 | S-4 | 0.08 | 20 |
| CS-N | 14.11 | 90 | S-5 | 0.08 | 20 |
| CS-S | 28.40 | 30 | S-6 | 0.08 | 30 |
| | | | S-7 | 0.07 | 30 |

**Supplementary Table S2:** MT3DMS parameter inputs for this study

| Parameter | Value |
|---|---|
| Longitudinal Dispersivity | 46 m* |
| Porosity | 0.2** |
| Ratio of horizontal transverse dispersivity to longitudinal dispersivity (TRPT) | 1.0*** |
| Ratio of vertical transverse dispersivity to longitudinal dispersivity (TRVT) | 0.05*** |
| Simulation time length | 20,000 days (54.8 yr) |

*lower limit in Glenn et al. (2003), **based on previously published range for volcanic rock (Earle, 2016)

*** set within typical ranges (Lan et al., 2015; Majumder and Bhattacharjya, 2017; Shuler et al., 2017)

**Supplementary Table S3**: Summary of DIN and GLY inputs, and attenuation in the MT3DMS model. Attenuation rate literature ranges are in parentheses, and the rate used in the model outside parentheses.

| | Source type | N-load (g/d) | Attenuation (%) | N-Load (after attenuation) (g/d) |
|---|---|---|---|---|
| DIN | OSDS | 21* | (38-52) 45* | 11.6 |
| | Piggeries | 38.1* | (82-90) 86* | 5.3 |
| | | Concentration (mg/L/yr) | Attenuation (%) | N-Load (after attenuation) (mg/L/yr) |
| | Agriculture | 3.96** | (47-81) 64* | 1.42 |
| | Natural | 0.006*^ | - | 0.006 |
| GLY | Agriculture | 84*** | 50[†] | 42 |
| | Urban | 42*** | 50[†] | 21 |

^ steady-state concentration, mg/L (not mg/L/yr) *value from Shuler et al. (2017)
**estimated annual concentration from World Bank for W. Samoa and Schilling and Streeter (2018)
*** value from Newton et al. (1984) for agriculture, and estimated as ½ of agriculture for urban
[†]calibrated rate to best fit observations in this study

**Supplementary Table S4**: Observed and modeled concentrations of GLY and DIN with the MT3DMS transport model, and the relative error at each point.

| | GLY (ng/L) | | | DIN (μg/L) | | |
|---|---|---|---|---|---|---|
| Sample Site | Observed | Modeled | Relative Error (%) | Observed | Modeled | Relative Error (%) |
| S-1 | 90 | 60 | 36 | 80 | 140 | -67 |
| S-3 | 80 | 40 | 55 | 60 | 70 | -9 |
| S-6 | 180 | 0 | 100 | 70 | 5 | 91 |
| FG-179 | 160 | 2 | 99 | 110 | 30 | 75 |
| CS-N | 160 | 300 | -91 | 250 | 260 | -1 |
| CS-S | 300 | 110 | 65 | 90 | 110 | -23 |

**Supplementary Table S5**: GLY and DIN fluxes calculated from baseflow and SGD derived from the hydrogeological model (MODFLOW) and solute concentrations from field observations, derived from the transport model (MT3DMS) with modeled groundwater discharge and solute distribution, and field observations of stream flow and solute concentrations. *Observed SGD is from Shuler et al. (2019), multiplied by the observed solute concentrations.

| | | GLY | | | DIN | | |
|---|---|---|---|---|---|---|---|
| | | MODFLOW | MT3DMS | Measured | MODFLOW | MT3DMS | Measured |
| Baseflow | Upper Reach (g/d) | 0.4 | 0.04 | | 170 | 240 | |
| | Lower Reach (g/d) | 0.1 | 0.3 | | 100 | 630 | |
| | Total Stream (g/d) | 0.5 | 0.34 | 0.3 | 270 | 860 | 300 |
| SGD | North Coast (g/d) | 0.1 | 0.1 | | 120 | 550 | |
| | Central Coast (g/d) | 0.2 | 0.1 | | 150 | 180 | |
| | South Coast (g/d) | 0.1 | 0.02 | | 40 | 30 | |
| | Total SGD (g/d) | 0.4 | 0.22 | 0.5 * | 310 | 760 | 360 * |
| Baseflow + SGD (g/d) | | 0.90 | 0.56 | 0.80 | 580 | 1620 | 660 |

**Supplementary Table S6**: Amounts and percent contribution to DIN and GLY loads at each observation point in the watershed from each point and non-point source considered in this study (piggeries, agriculture, OSDS, natural, domestic) derived from the MT3DMS model.

| Sample Site | All N-sources (µg/L) | Piggeries(µg/L) | Agriculture (µg/L) | OSDS (µg/L) | Natural (µg/L) | All GLY sources (ng/L) | Domestic (ng/L) | Agriculture (ng/L) |
|---|---|---|---|---|---|---|---|---|
| S-1 | 137 | 7 | 0.05 | 126 | 4 | 58 | 49 | 9 |
| S-3 | 67 | 5 | 0.03 | 58 | 4 | 33 | 21 | 12 |
| S-6 | 7 | 0.08 | 0 | 4 | 3 | 0 | 0 | 0 |
| FG-179 | 27 | 3 | 0.02 | 21 | 3 | 2 | 2 | 0 |
| CS-N | 254 | 2 | 0.39 | 247 | 5 | 297 | 181 | 116 |
| CS-S | 112 | 20 | 0.19 | 86 | 6 | 105 | 101 | 4 |
| Percent contribution to total load (%) | | 6.1 % | 0.1 % | 89.8 % | 4 % | | 71.5% | 28.5% |