APPENDIX C. POLLUTANT LOAD MODELING

One element of EPA's watershed planning criteria is to estimate existing and future watershed pollutant loads to help prioritize management actions. To this end, we used the Watershed Treatment Model (WTM), Version 3.0 (Caraco, 2013)--a public-domain, Microsoft Excel-based spreadsheet model used to estimate annual watershed pollutant loads for total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), fecal coliform bacteria (FC), and runoff volume. The WTM was applied to four major stream catchments within the Achugao Watershed (As Agatan, Saddok Dogas, Achugao, and San Roque) as illustrated in **Figure 1**. It is worth noting that these catchments include areas of direct drainage to Tanapag Lagoon (not strictly delineated to each stream outlet).

The model relies principally on primary inputs (e.g., annual rainfall, land use, and soils) to apply standard event mean concentrations and runoff coefficients to generate pollutant load and runoff volume estimates. The model allows the user to incorporate secondary pollutant sources, such as wastewater systems, marinas, channel erosion, and livestock, if known. In addition, the WTM allows the user to predict future loads based on land use changes, new development, and treatment measures (stormwater management practices, stream buffers, regulatory and educational programs, wastewater improvements, street sweeping, etc.) making it an ideal tool for watershed planning. Depending on the quality of input data, the WTM can be used to quickly generate relative comparisons across watersheds or implementation scenarios. Readily available GIS data from sources such as DCRM, CUC, NOAA, NRCS, and others are used to generate much of the input data. Field observations on pollutant sources, stream characteristics, and other watershed conditions can be used to adjust model input variables. Unless the user inputs watershed-specific data, the WTM uses default values derived from US national averages for the primary and secondary sources.

INPUTS AND ASSUMPTIONS

Tables 1-4 and **Tables 5-7** summarize key data input assumptions used to generate existing and future loads, respectively. These can (and should) be adjusted as more information is collected, particularly if numerical loads are considered important. The model inputs are based on a combination of available mapping information and our observations of watershed conditions, existing management measures, and potential opportunities for restoration. It should be noted that:

- Not all input parameters were fully vetted during field investigations (e.g., livestock, illicit discharges). Some of the GIS data used may not accurately reflect conditions (e.g., impervious cover, previously burned areas). No model calibration or validation was conducted using water quality data.
- The model does not account for routing, attenuation, or subsurface flows in the watershed. The smaller the watershed area modeled the better.
- Stream erosion and shoreline stabilization is not well accounted for in the model, although the user can provide a broad estimate of the contribution of stream erosion to TSS loading.
- The model estimates load to groundwater from infiltration practices and septic systems but does not include those loads in the total surface loads to the receiving waters. Groundwater loads are reported separately.
- Surface loads to receiving waters includes both coastal waters and the freshwater wetland complexes in Achugao. Separate loads to the existing wetlands could be estimated, and amount of treatment offered by those wetlands, could be estimated by modeling contributing drainage areas to the wetlands first and then treating the wetlands as BMPs prior to coastal discharge.

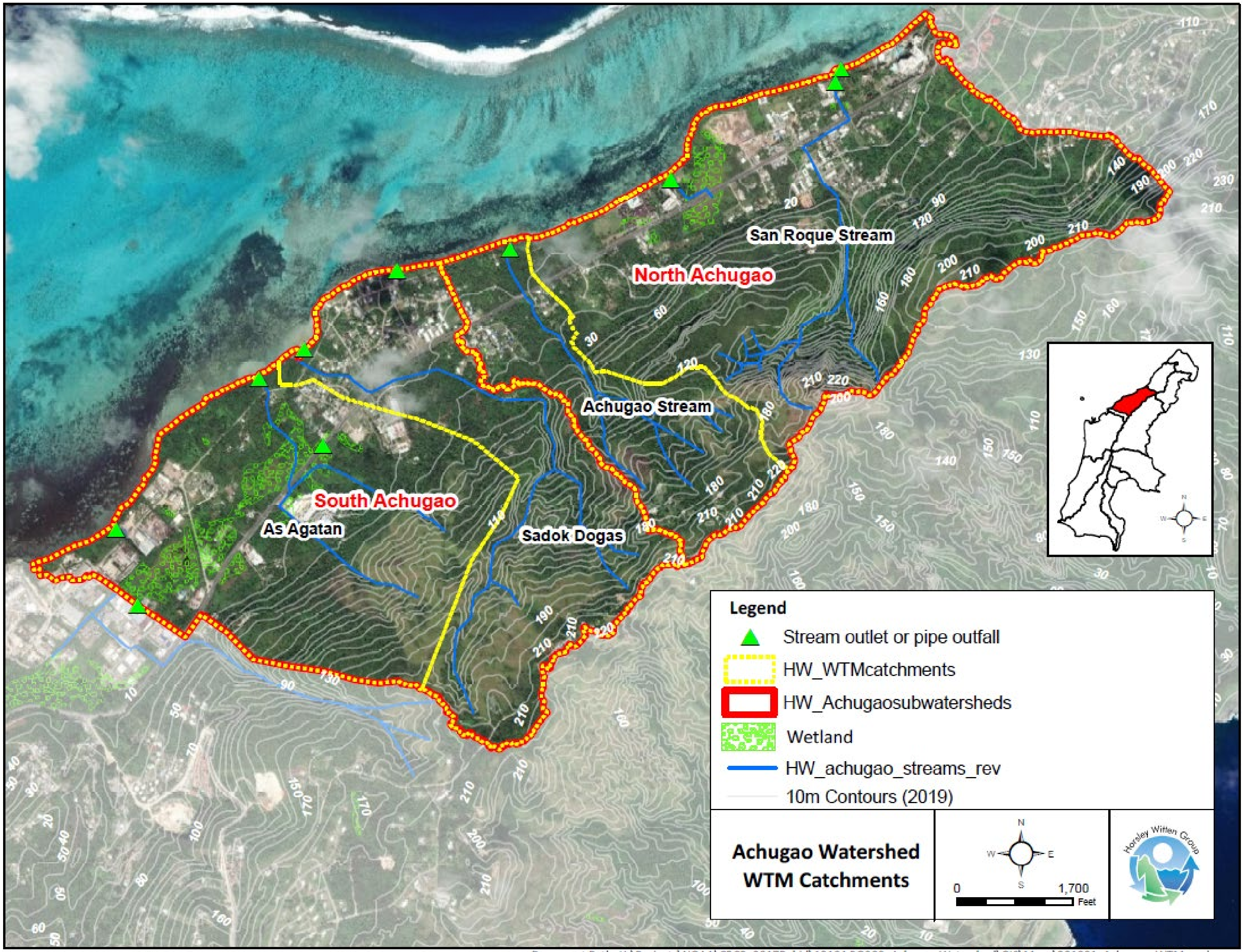

Figure 1. Four stream catchments included in the WTM model runs

Table 1. Input Data Used to Estimate Existing Loads

Input Parameter	Value				Description
	As Agatan	Dogas	Achugao	San Roque	
PRIMARY SOURCES					
Avg annual rainfall	85 inches				Interpolation from 2009 CNMI Stormwater Manual.
Watershed Area (acres)	436	336	190	645	Reduced watershed area by consensus during watershed meetings in January 2020 to exclude Tasi stream catchment that drains to DFW beach. Remaining boundary based on 2017 LIDAR-derived basin mapping from NOAA/CRM.
Land Use	**See Table 2.** DCRM/NOAA provided the most current landuse GIS layer, which was incomplete and did not distinguish between L-H density residential. HW updated residential areas based on observations, aerial imagery and the USFS Vegetation Classification, and by selecting all parcels with buildings or were classified as urban land. HW reclassified Open Space area using the USFS Vegetation Classification to find more accurate estimates for agricultural land, beach/recreation area and forested area. We did not adjust for commercial areas or multifamily residential. The land use data contains a transportation class, which we classified as paved or unpaved.				
Impervious Cover (acres/% watershed using GIS layer or by acres/% using coefficients in WTM)	NOAA: 54 acres (12%) or WTM: 75 acres (17%)	NOAA: 34 acres (10%) or WTM: 51 acres (15%)	NOAA: 15 acres (8%) or WTM: 18 acres (9.5%)	NOAA: 66 acres (10%) or WTM: 105 acres (17%)	IC is used in model to estimate runoff volume. There are two options for deriving IC: 1) use NOAA 2005 IC layer; or 2) use default impervious coefficients for land use categories. We used option 2 in the model but adjusted residential default values using 2019 LandSat satellite imagery from USGS to calculate the Normalized Difference Vegetation Index to estimate non-vegetated land cover for each residential category. An analysis of average impervious cover by other land use types was outside the scope of this effort.
Pollutant Event Mean Concentrations (EMCs)	See **Table 3.** EMCs and loading rates from various land uses are typically based on values from the National Stormwater Quality Database (NSQD), which is a summary of stormwater data from over 200 jurisdictions across the US (Pitt et. al., 2003). Land uses with impervious cover are assigned an EMC. Land uses without impervious cover use an assigned loading rate. We have adjusted the default values for sediment using data from the USVI/PR, but they should be adjusted for CNMI as data becomes available.				
Hydrologic Soil Groups (% of watershed)	22% HSG A; 2% HSG B; 10% HSG B/D; 29% HSG C; 37% HSG D	10% HSG A; 8% HSG B; 60% HSG C; 21% HSG D	3% HSG A; 17% HSG B; 36% HSG C; 43% HSG D	9% HSG A; 16% HSG B; 2% HSG B/D; 10% HSG C; 63% HSG D	Based on NRCS mapping. The HSGs are used to estimate surface conditions for infiltration potential, with A soils generally having a high permeability rate (e.g., sandy soils) and D soils generally having a low permeability rate (e.g., clay soils).

Input Parameter	Value				Description
	As Agatan	Dogas	Achugao	San Roque	
Depth to Groundwater (% of watershed)	12% <3 ft; 16% 3-5f; 72% >5 ft	2% <3 ft; 8% 3-5ft; 90% >5 ft	2% <3 ft; 8% 3-5ft; 90% >5 ft	4% <3 ft; 6% 3-5ft; 90% >5 ft	Based on NRCS soil mapping (depth to groundwater estimates) plus an adjustment of 2% for shoreline and up to 8% for transition zone when NRCS maps say 100% >5ft. Shallow depths to groundwater (e.g., <24") can signify a higher potential for nutrients to enter groundwater, while deeper depths (e.g., > 48") can provide better pollutant removal.
Stream length (miles)	1.4	2.5	1.7	2.2	DCRM/NOAA hydrography shapefile, modified by HW. Need to update with DCRM 2020 stream walk mapping and/or IR data layer.
SECONDARY SOURCES					
Sanitary Sewer Overflows (SSO) (pipe network miles/#overflows)	1.3 miles # SSOs:3.25	2.1 # SSOs:5.25	0.6 # SSOs:1.5	2.6 # SSOs:6.5	Most of the developed watershed is sewered (see CUC's Sadog Tasi sewershed boundaries). Length of sewer lines are from CUC dataset, and include gravitational sewer line, pressurized sewer line and lateral lines. We assume 2.5 sewer overflows per mile (this could be low).
Onsite Disposal Systems (OSDS) (#dwellings total/# with OSDS/%OSDS within 100' of stream)	150/68/15% within 100' of stream Includes 1/3 worker barrack units 50% OSDS failure rate due to known issues	170/8/50% within 100' of stream 40% failure rate of OSDS	43/7/30% within 100' of waterway Standard 30% OSDS failure rate	333/55/2% within 100' of stream Aqua and Kensington are on sewer Standard 30% OSDS failure rate	Sewage impacts are estimated from # dwellings, standard nutrient and bacteria concentrations of raw sewage, and default assumptions of volume generated per dwelling. # of dwellings is estimated from building footprint GIS, land use, and aerial photos. If a building is outside of CUC mapped sewer service area, it is counted as having OSDS. Dwellings include # of residential buildings plus 1/3 of commercial buildings and 1/3 the # of hotel rooms or units in worker barracks (see **Table 4**). We assumed <u>all</u> OSDS are conventional design (i.e., not enhanced for nutrient removal) with default concentrations and removal efficiencies.
Illicit discharge into the storm drain or stream (fraction illicitly connected)	10% of residents and businesses (of 33 total businesses)	10% (of 15 total businesses)	5% (of 25 total businesses)	10% (of 30total businesses)	This is non-stormwater runoff discharge into storm drain or stream. Not based on any CUC data, just best professional guess. Model default values used for concentrations in sewage and washwater. # of businesses derived from estimate based on # of buildings in commercial land.
Livestock	100 pigs and 300 chickens	75 pigs and 100 chickens	50 pigs and 150 chickens	150 pigs and 400 chickens	Not based on any data. This is probably low by an order of magnitude. It doesn't account for dogs...

Input Parameter	Value				Description
	As Agatan	Dogas	Achugao	San Roque	
Stream Channel Erosion	Low. 25% of total sediment load				Not based on any field data. Selected default method 1 in the model that back calculates a % for channel erosion based on total sediment load and miles of stream. Stream visual assessments did not indicate level of erosion, however new assessments are anticipated to do so.
EXISTING MANAGEMENT PRACTICES					
Structural stormwater BMPs (post-construction)	**See Table 5**. We included several BMPs we were aware of in the model that currently provide some level of stormwater management. There are likely more that BECQ and DPW are aware of. We used default pollutant removal rates for each type of practice, assumed 50% capture rate for target volume (90th percentile storm of 1.5 inch), estimated area managed by field observations, and assumed maintenance of facilities was low.				
Erosion and Sediment Control	50% program efficiency	25% program efficiency	50% program efficiency	50% program efficiency	CNMI has a relatively strong ESC inspection program. Program efficiency factors could probably be higher. Low points for Imperial Casha
Catch basin cleaning	none	none	none	none	This could be refined based on DCRM, DPW, and CUC guidance.
Riparian Buffers (% impacted/OK miles)	43%; 0.8 miles OK	45%; 1.4 miles OK	11%; 1.5 miles OK	22%; 1.7 miles OK	Assumes 50 ft buffer width X length of stream, with 0.4 regulatory protection factor.

Table 2. Area, % cover, and EMCs for each land use category

LU Category	Area (Acres)				% Cover		Event Mean Concentrations			
	Agatan	Dogas	Achugao	San Roque	Imper.	Turf	TN* (mg/l)	TP (mg/l)	TSS (mg/l)	FC (MPN/ 100 ml)
LDR > 1 ac	21.2	10.3	22.1	98.2	20%	16%	1	0.2	102	20300
MDR 0.25-1 ac	6.6	25.3	12.0	25.9	40%	12%	1	0.2	102	20300
HDR <0.25 ac	18.4	14.4	4.4	18.0	65%	7%	1	0.2	102	20300
Municipal/Inst.	6.7	10.2	0	4.0	72%	6%	1.2	0.22	49	20000
Recreational/Beach	22.9	4.1	0	0.1	10%	72%	1.2	0.22	49	20000
Commercial	1.0	4.0	0	43.2	72%	6%	1.2	0.39	56	20000
Roadway -Paved	23.0	15.0	3.0	21.7	100%	0%	1.2	0.16	36	13700
Roadway -Unpaved	4.0	4.4	3.2	8.4	90%	2%	1.2	0.24	2895	13700
Active Construction	4.0	22	0	16.2			1	0.2	680	0
Industrial	40.1	0	0.3	1.4	53%	9%	2.2	0.22	81	20000
	Area (Acres)				**% Cover**		**Annual Loading Rate**			
	Agatan	**Dogas**	**Achugao**	**San Roque**	**Imper.**	**Turf**	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	FC (# billion)
Forest/Park or Open	234.0	226	145	388.4	0%	0%	1.8	0.25	147	12
Ag	11.2	0	0	5.8	0%	0%	5.3	1.2	147	39
Open Water/wetland	43	0.2	0.1	13.7	--	--	12.8	0.5	155	--
Total Acres	**436**	**336**	**190**	**645**			--			

*TN values used here are considerably lower than standard concentrations for urban runoff which are generally 2 mg/L or higher for mainland US. Lower values were based on assumption of lack of fertilizer usage in CNMI.

Table 3. Existing stormwater management practices and applied pollutant removal rates

BMP	**Contributing Drainage Area** (estimated acres)								% Removal *			
	As Agatan		Dogas		Achugao		San Roque		TN	TP	TSS	FC
	Total	*IC*	*Total*	*IC*	*Total*	*IC*	*Total*	*IC*				
Coral road BMPs & sediment traps					1	0.7			0%	60%	80%	50%
Vegetated swale			3.2	1.0					30%	25%	60%	0%
Dry detention basin									10%	15%	55%	0%
Ponding basin (wet)			3.7	1			10	8	30%	50%	80%	70%
Constructed wetland									25%	50%	75%	80%
Bioretention/rain garden			0.5	0.4					65%	55%	85%	90%
Infiltration (various)			0.2	0.2			3.5	3	55%	65%	95%	85%
Rooftop disconnection									25%	25%	85%	0%
Rain tanks and cisterns									40%	40%	40%	0%
Total Acres			**7.6**	**2.6**	**1.0**	**0.7**	**13.5**	**11.0**				

*removal rates when functioning properly. Should be updated per the CNMI stormwater manual.

Table 4. Number of dwelling units and rooms for hotels

Name	# rooms/units	Name	# rooms/units
Worker barracks- As Agatan	100	Villora condotel (not constructed)	150
Kensington- San Roque	313	New Century Hotel--redevelopment	48
Aqua-San Roque	91	Globe- San Roque, under construction	536
Plumeria- San Roque (closed)	100	Casha Imperial- Dogas, under construction	1184

*room estimates based on BECQ permit database and internet research

Table 5. Future management measures applied in the model

Input Parameter	As Agatan	Dogas	Achugao	San Roque
Septic System education, repair, upgrade	• Education program reaches 30% of population • 25% systems inspected • 100% willing to repair/upgrade			
Remove Illicit Connection	• 30% of system surveyed • 100% of repairs made			
SSO repair and abatement	• Goal of 100% reduction • 50% complete			
Stormwater retrofits (See **Table 6**)	15 additional acres managed (90% impervious)	13 additional acres managed (47% impervious)	none	69 acres managed, including retrofit of existing ponds at Kensington and completed BMP at Globe (51% IC)
	• assumed 50% capture rate for target volume (1.5 inch) • low maintenance			
Impervious Cover Disconnection Program- Residential	• Program in place • 1200 sq ft typical roof size, 25% of land where applicable, • 8% of population reached and 10% willing to participate			
Redevelopment improvement	0.5 acres (New Century Hotel) reduces impervious and turf cover on site by 10%	none		5 acres (Plumeria) reduces impervious and turf cover on site by 10%
Erosion and Sediment Control	Increase from 50% to 80% program efficiency	Increase from 25% to 80% program efficiency	Increase from 50% to 80% program efficiency	
Catch basin cleaning	Semi-annual cleaning for 5 acre contributing drainage area		none	Semi-annual cleaning for 10 acre contributing drainage area
Street sweeping	Monthly sweeping of 10 total acres streets using mechanical sweeper	No street sweeping		
Riparian Buffers	Enhance 0.5 additional miles of stream buffer (100 ft width)	Replant additional 0.2 miles of stream (100 ft width)	No additional buffer enhancement	
	Implement specific buffer education, enforcement, and regulations			
Pet waste management	• Implement education program • 30% of households with dogs • 50% made aware and 25% will change behavior			Same except 5% of households with dogs (hotels account for a large % of households)

Table 6. Future stormwater management practices (retrofits) modeled

Stormwater BMP	Drainage Area Managed (Total acres/Impervious acres)			
	As Agatan	Dogas	Achugao	San Roque
Bioswales	15/14	7.3/5.2		24.7/11
Wet Pond		3.7/1.0		
Constructed Wetland				18.9/14.2
Permeable pavement				2/2
Sand filter				7.7/3.9
Bioretention (various, TBD)		2.3/1.0		13.8/5.7
Road stabilization			none	2.4/0.8
Total	**15/14**	**13.3/7.2**		**69.2/35.3**

Table 7. Future land use changes and new development assumptions

As Agatan	Dogas	Achugao	San Roque
• 4 acres of active current construction becomes commercial land • 10 acres of currently undeveloped land is converted to 5 commercial acres and 5 medium density residential acres • Meet 80% TSS and bacteria, 40% nutrients, 50% runoff reduction target • 0.2 mile sewer connections • No new septic systems • No illicit discharges	• 22 acres of active current construction becomes commercial land • 10 acres of currently undeveloped land is converted to 10 commercial acres • Meet 80% TSS and bacteria, 40% nutrients, 50% runoff reduction target • 0.2 mile sewer connections • No illicit discharges	• 10 acres of currently undeveloped land is converted to 10 low-density residential acres • Meet 80% TSS and bacteria, 40% nutrients, 50% runoff reduction target • 5 new conventional septic systems	• 16.2 acres of active current construction becomes commercial land • Meet 80% TSS and bacteria, 40% nutrients, 50% runoff reduction target • 0.2 mile sewer connections to connect Beverly • No illicit discharges

RESULTS

While the WTM can be used to generate qualitative nutrient, TSS, and bacteria loads, it is better for comparing relative contributions between subwatersheds and management scenarios. At this time, we have only run a preliminary model to estimate existing and predict future pollutant loads based on an initial assessment of conditions and restoration opportunities. These estimates will be revisited as part of the watershed plan with a focus quantifying the potential load reduction benefits of priority implementation projects.

Table 8 summarizes model results for existing conditions, future management options/watershed treatment, and with future development. Quantification of the numeric annual load, while useful, is highly dependent on specific data inputs, such as runoff concentrations, number of pigs, volume of sewer overflows, etc. We don't recommend putting much stock in these numbers until more refined input data can be obtained and the model compared with findings from the water quality monitoring program.

Table 8. Loads to Surface Waters

Subwatershed Scenario	TN (lb/year)	TP (lb/year)	TSS (lb/year)	Fecal Coliform (billion/year)	Runoff Volume (acre-feet/year)
As Agatan					
existing	4,078	570	423,319	435,813	591
w future BMPs	3,680	506	372,620	334,401	552
% reduction	**10%**	**11%**	**12%**	**23%**	7%
w future development	3,829	549	380,312	344,627	599
Dogas					
existing	2,228	383	474,018	410,702	421
w future BMPs	1,904	323	377,866	300,199	409
% reduction	**15%**	**16%**	**20%**	**27%**	3%
w future development	2,287	447	393,973	326,527	532
Achugao					
existing	786	132	156,244	74,738	126
w future BMPs	760	126	156,034	58,890	126
% reduction	3%	5%	0%	**21%**	0%
w future development	843	142	161,457	62,989	142
San Roque					
existing	4,675	863	791,397	818,292	835
w future BMPs	3,902	707	660,234	472,362	789
% reduction	**17%**	**18%**	**17%**	**42%**	6%
w future development	4,088	769	666,986	485,791	853

Figures 2-4 illustrate which of the catchments and sources are identified by the model as the biggest contributors of annual pollutant loads to Tanapag Lagoon from the Achugao watershed.

For the purposes of the Achugao WMP, it is the relative change in value between existing and future conditions, all data input assumptions being equal, that is the most relevant. Determining the full, optimal extent of management actions required to meet a reduction target is an iterative process. We, however, only ran the WTM one time with one set of potential future management activities. Several takeaways include:

1. The model identifies San Roque as the largest total contributor of annual pollutants of the four catchments. While it is significantly larger than the other catchments and (depending on the data source) one of the most urbanized, the water quality in this part of the lagoon is better than in the Tanapag area. As Agatan contributes a similar level of nutrients to Tanapag Lagoon likely due to the heavily developed Lower Base and issues with onsite wastewater systems. Dogas and Agatan contribute only half of the sediment and bacteria loads as San Roque; however, if the model accounted for burned lands/grasslands differently than forest cover, this would not likely be the case. Dogas construction sites and upland burned areas may contribute more sediment load than the model currently estimates. Achugao is the smallest and least developed catchment and is predicted to generate the lowest pollutant loads. Retrofit and stabilization efforts may be the most effective in San Roque and As Agatan.

2. Under the treatment scenarios modeled, the most effective treatment options to reduce nutrients in the watershed are wastewater improvements and illicit discharge removal, stormwater retrofitting, riparian buffer improvements, and erosion control. Understanding the influence of illicit discharges will be critical to refining a management approach. Excessive nutrient loading can lead to reduced dissolved oxygen, which Achugao area is currently impaired. To reduce TSS, erosion and sediment control at construction sites and stormwater retrofits (including unpaved road improvements) are likely to have the most impact. Reforestation would likely be a significant activity as well, but the model currently doesn't distinguish between forest, grassland, and previously burned areas.
3. While DCRM's water quality monitoring program tracks different indicator bacteria, initial results for load reductions ranging from 21%-42% for bacteria are encouraging. The 2017 bacteria TMDL establishes a wet weather geomean reduction range of 20-88%. The largest reductions seen in the model are gained through illicit discharge disconnections, retrofits, SSO repairs, and enhanced riparian buffers. MST data shows that most of bacteria in water quality samples are from dogs. More information is needed to accurately model the impact of livestock and dogs on watershed loads and better evaluate the real influence of sanitary overflows and illicit connections on the system.
4. There is a lot of room to achieve load reduction in the watershed, even if sanitary sewer improvements have mostly been completed. There is currently very little area being captured by stormwater management practices and enforcement of erosion control at construction sites could be improved.
5. Future development could quickly undue the gains earned through retrofitting and other watershed restoration actions. Anticipated development in Dogas and Achugao catchments, for example, actually show a 3-17% increase in loads under the actively pending development projects.

It is important to keep in mind that a model is only as good as the data that goes into it. The purpose of this exercise was to identify the load reduction potential of some identified restoration projects. The WTM offers a lot of flexibility to accommodate better data as it becomes available, but also provides a comprehensive framework that is perfect for big picture watershed planning purposes. To further utilize the model, consider the following:

1. There are a few projects, such as reforestation, education, and better maintenance and enforcement, that could be put into the model so their benefits can be quantified.
2. Review water quality data for the watershed to evaluate how representative the model results are at this stage.
3. Refine input variables where assumptions are wrong and data is readily available to add or correct input, such as primary land use revisions (i.e., updated impervious cover, active construction, separation of forest from grasslands and previously burned areas), and secondary sources that other agencies have better insight on (e.g., # of SSOs, # of septic systems, livestock estimates).

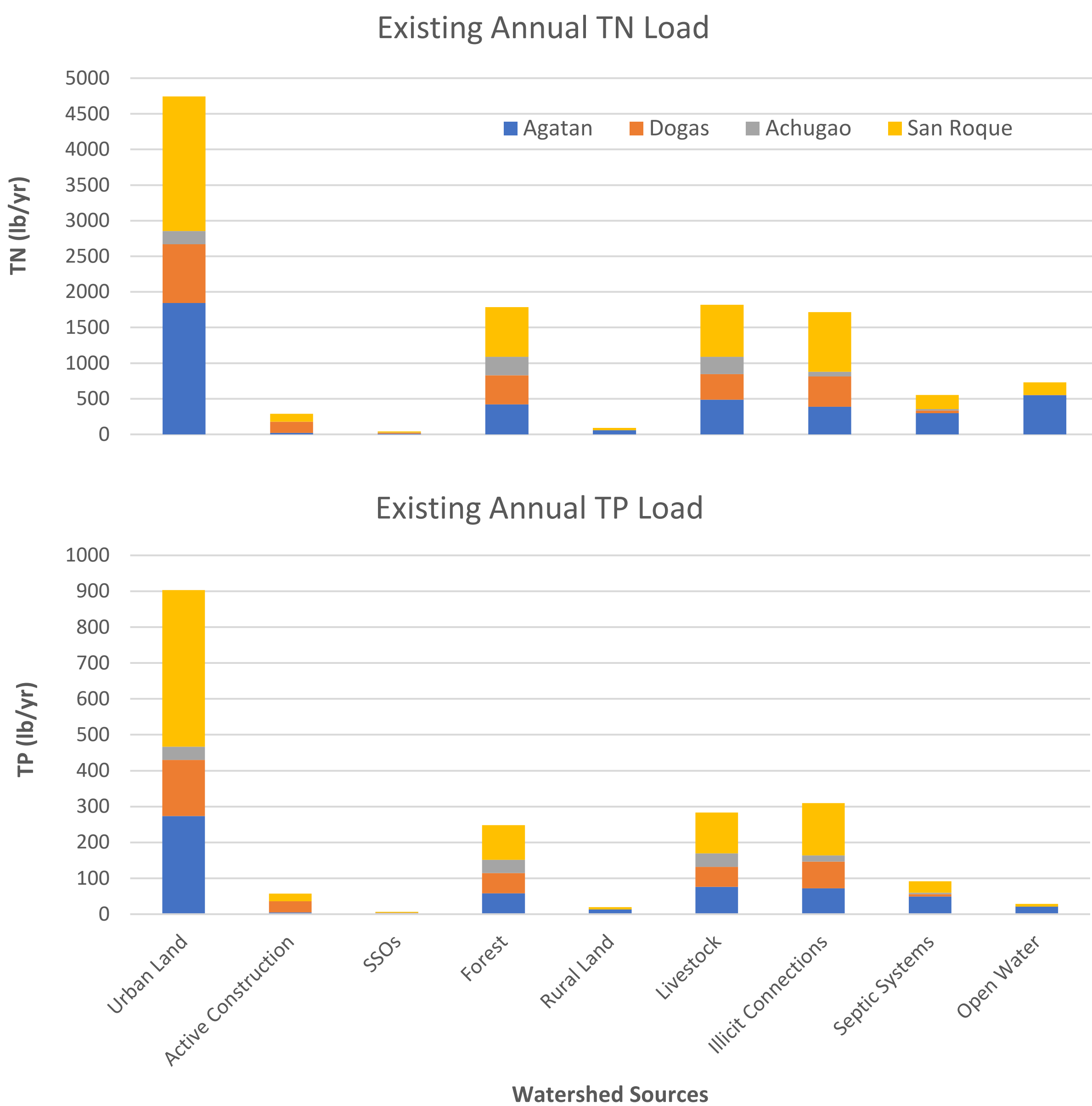

Figure 2. Sources of nutrient loads to surface waters by subwatershed

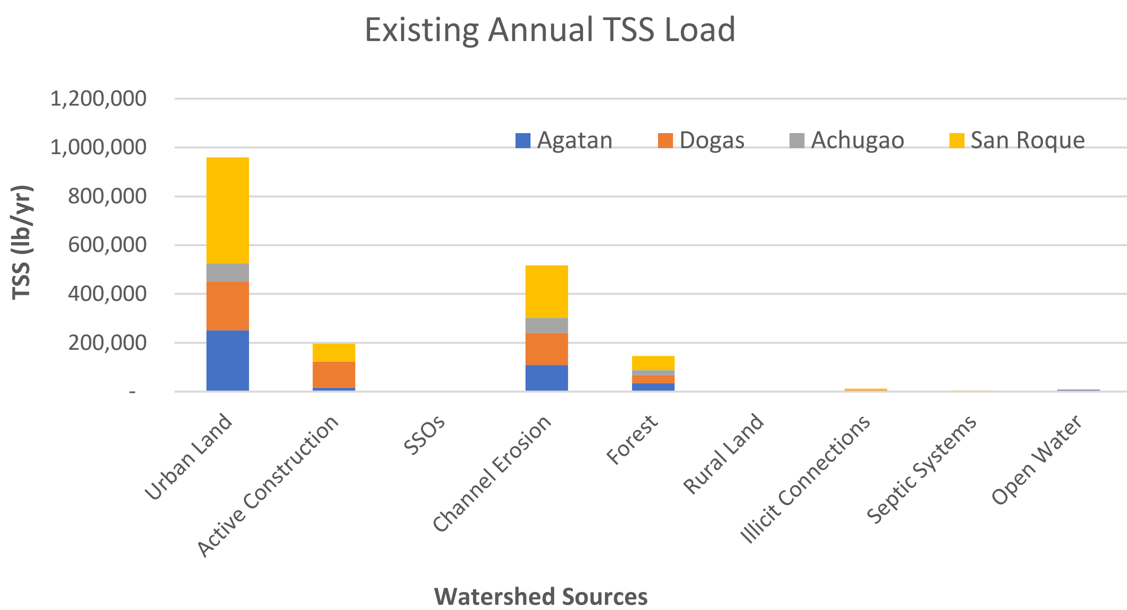

Figure 3. Sources of sediment loading to surface water by subwatershed

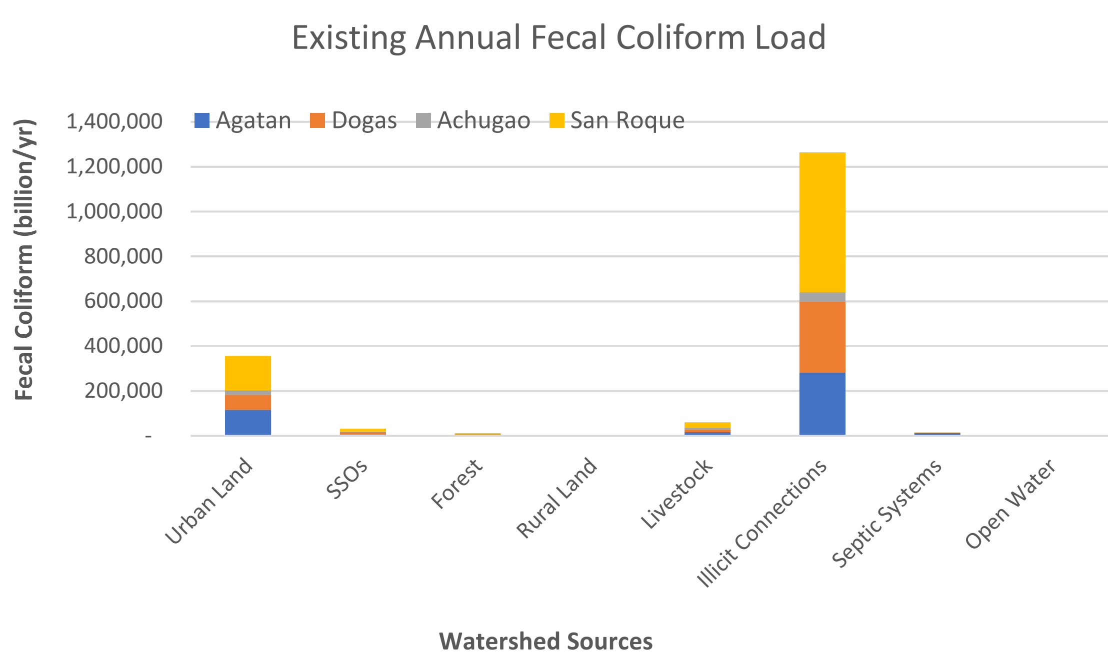

Figure 4. Sources of bacteria loading to surface water by subwatershed