MODELING SUPPORT FOR THE ATTOYAC BAYOU ASSESSMENT USING SELECT

Kyna Borel, Department of Biological and Agricultural Engineering, Texas A&M University; Lucas Gregory, Texas Water Resources Institute; R. Karthikeyan, Department of Biological and Agricultural Engineering, Texas A&M University

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Texas AgriLife Research
Department of Biological and Agricultural Engineering, Texas A&M University
Texas Water Resources Institute

Prepared by
Kyna Borel, Department of Biological and Agricultural Engineering, Texas A&M University
Lucas Gregory, Texas Water Resources Institute
and
R. Karthikeyan, Department of Biological and Agricultural Engineering, Texas A&M University

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Abbreviations

CCN -- Certificate of Convenience and Necessity
CFU – Coliform Forming Units
EPA – U.S Environmental Protection Agency
GIS – Geographical Information Systems
NASS – National Agriculture Survey Statistics
NRCS – Natural Resources Conservation Service
OSSF – On-Site Sewage Facilities
SELECT – Spatially Explicit Load Enrichment Calculation Tool
TMDLs – Total Maximum Daily Loads
TSSWCB – Texas State Soil and Water Conservation Board
TWRI – Texas Water Resources Institute
USDA – U.S Department of Agriculture
WPP – Watershed Protection Plans
WWTF – Waste Water Treatment Facility

1. POTENTIAL *E. coli* SOURCES USING SPATIALLY EXPLICIT LOAD ENRICHMENT CALCULATION TOOL (SELECT)

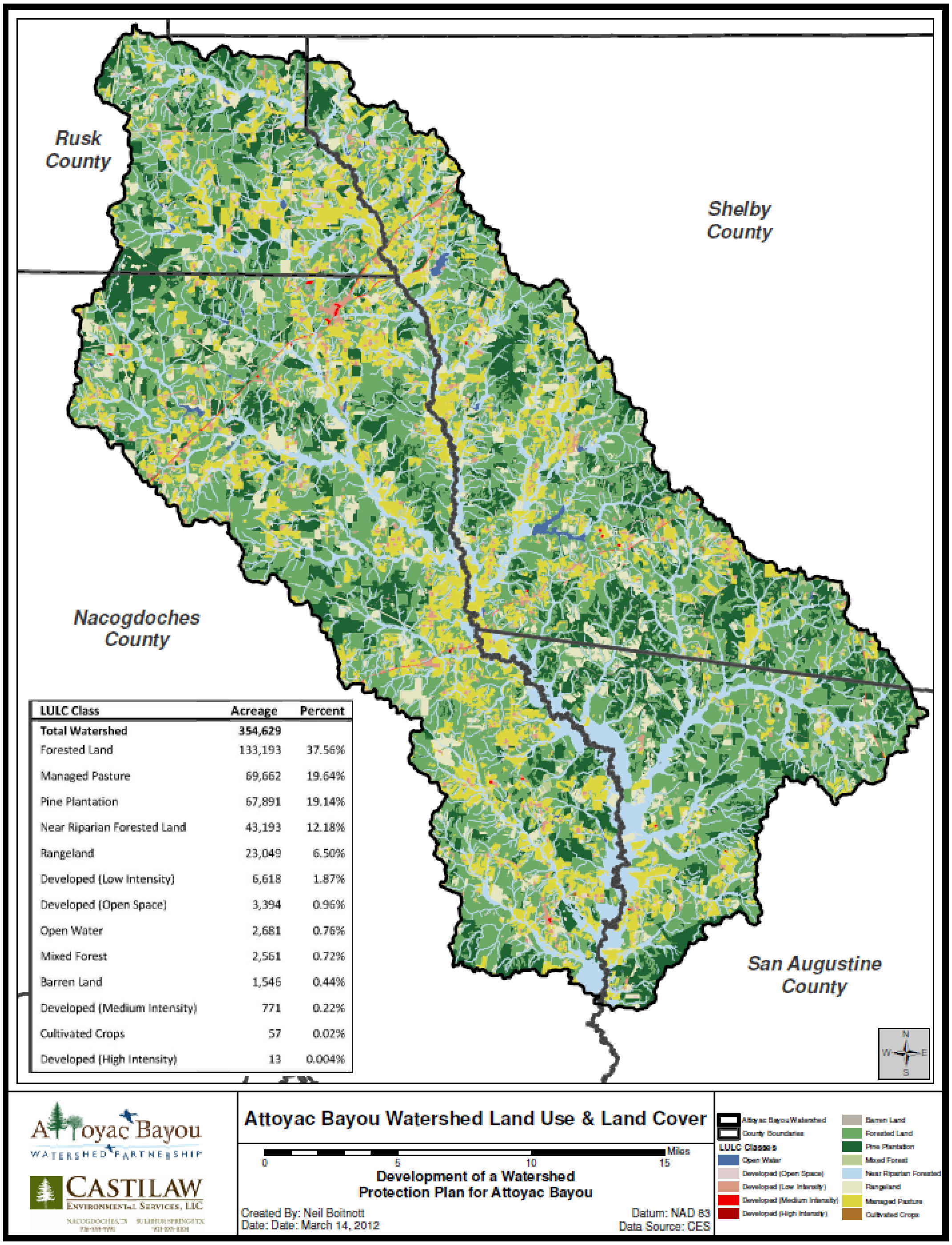
The Spatially Explicit Load Enrichment Calculation Tool (SELECT) methodology developed by Biological and Agricultural Engineering Department and Spatial Sciences Laboratory at Texas A&M University was used to independently characterize potential *E. coli* sources and estimate daily potential *E. coli* loads for the Attoyac Bayou watershed. SELECT is an analytical approach for developing an inventory of potential bacterial sources, particularly nonpoint source contributors, and distributing their potential bacterial loads based on land use and geographical location. A thorough understanding of the watershed and potential contributors that exist is necessary to estimate and assess bacterial load inputs. Land use classification data and data from state agencies, municipal sources, and local stakeholders on the number and distribution of pollution sources are used as inputs in a Geographical Information Systems (GIS) software format. The watershed is divided into multiple smaller subwatersheds based on elevation changes along tributaries and the main segment of the water body. Pollutant sources in the landscape can then be identified and targeted where they are most likely to have significant effects on water quality, rather than looking at contributions on a whole-watershed basis.

SELECT is a pathogen load assessment tool, which can be combined with a watershed-scale water quality model using spatially variable governing factors such as land use, soil condition, and distance to streams to support Total Maximum Daily Loads (TMDLs) and Watershed Protection Plans (WPPs). This tool can be used to estimate the actual contaminant loads resulting in streams when used in conjunction with a fate and transport watershed model. SELECT simulated potential *E. coli* loadings in the watersheds resulting from various sources based on user defined inputs such as stocking rates, animal populations, location of Waste Water Treatment Facilities (WWTFs), and *E. coli* production rates resulting from various sources.

Visual outputs of the program allow a decision maker or stakeholder to easily identify areas of a watershed with the greatest potential for contamination contribution and consider that information in formulating management strategies to include in a TMDL or WPP. Specific model details and information about its development can be found in Teague et al., 2009 and Riebschleager, 2008.

1.1. Land Use Analysis

The land use for the Attoyac Bayou watershed was categorized into 13 different categories and consists mostly of forested land, near riparian forest and pine plantation. Managed pasture also makes up a significant portion of the watershed (Figure 1, 2 and Table 1).



LULC Class	Acreage	Percent
Total Watershed	354,629	
Forested Land	133,193	37.56%
Managed Pasture	69,662	19.64%
Pine Plantation	67,891	19.14%
Near Riparian Forested Land	43,193	12.18%
Rangeland	23,049	6.50%
Developed (Low Intensity)	6,618	1.87%
Developed (Open Space)	3,394	0.96%
Open Water	2,681	0.76%
Mixed Forest	2,561	0.72%
Barren Land	1,546	0.44%
Developed (Medium Intensity)	771	0.22%
Cultivated Crops	57	0.02%
Developed (High Intensity)	13	0.004%

Figure 1. Land Use Distribution in the Attoyac Bayou Watershed.

Table 1. Land Use Distribution in the Attoyac Bayou Watershed by Acreage.

Land Use Land Cover Class	Acreage
Forested Land	119,270
Managed Pasture	69,662
Pine Plantation	67,891
Near Riparian Forested Land	57,116
Rangeland	23,049
Developed (Low Intensity)	6,618
Developed (Open Space)	3,394
Open Water	2,681
Mixed Forest	2,561
Barren Land	1,546
Developed (Medium Intensity)	771
Cultivated Crops	57
Developed (High Intensity)	13
Total	**354,629**

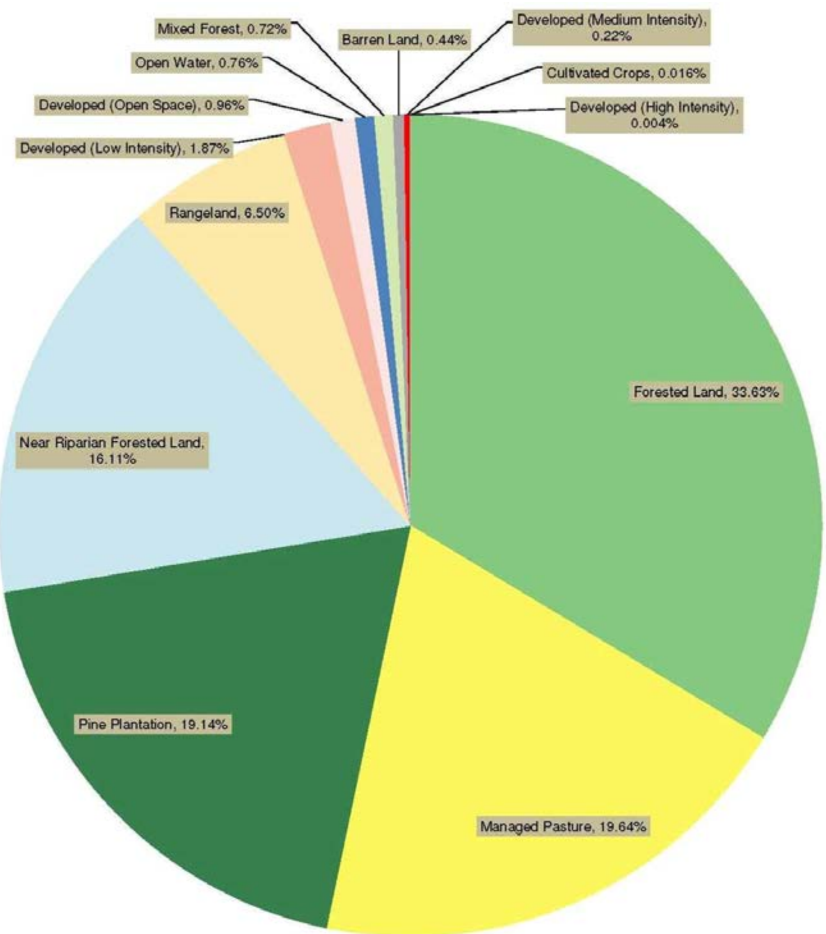


Figure 2. Land Use percentages in the Attoyac Bayou Watershed.

1.2. Potential *E. coli* Sources Modeled

All birds and mammals are sources of *E. coli* and those present in the watershed can feasibly contribute *E. coli* to the Attoyac Bayou. However, each watershed is different and not all potential contributors are likely to contribute significant amounts of bacteria to the water body. Additionally, sufficient information on species population, *E. coli* concentration and feces production rates are often unavailable thus limiting the ability to effectively model potential *E. coli* contributions from that respective source.

Discussions were held with watershed stakeholders to determine what potential *E. coli* sources in the watershed should be evaluated. Two primary factors were used in determining which sources should be modeled. These included abundance of the source in the watershed and whether sufficient information is available to effectively model the source. The results of these discussions were that cattle, deer, dogs, feral hogs, horses, hunting camps, poultry, on-site sewage facilities (OSSFs) and WWTFs warranted modeling and that sufficient information was available for each source to be effectively modeled.

The following sections describe how each potential *E. coli* source was considered in estimating total potential *E. coli* loads resulting from the watershed. All modeled parameters were discussed at length with the stakeholders in the Attoyac Bayou WPP development process.

1.2.1. Livestock –Cattle

A total of 23,646 cattle were uniformly distributed over rangeland and managed pasture land uses in the watershed. This number was derived by averaging the number of cattle in the watershed as indicated by stakeholder surveys. These numbers are slightly lower than livestock estimates based on USDA National Agriculture Survey Statistics (NASS) and by applying Natural Resources Conservation Service (NRCS)-recommended stocking rates to appropriate land uses. Recent drought conditions in the watershed are the primary driver for stakeholders to choose these lower numbers. An *E. coli* production rate of 2.63×10^9 CFU per animal per day was used in the model and was calculated using a fecal coliform density of 2.30×10^5 CFU per gram, a fecal production of 40 pounds per animal unit per day, and a fecal coliform to *E. coli* conversion of 0.63 which was derived by dividing the *E. coli* water quality standard of 126 cfu/100 mL with the fecal coliform standard of 200 cfu/100 mL. Each of these numbers and the land use land cover classes to apply this source to was selected by watershed stakeholders and the project team. The total potential *E. coli* loads for cattle (Figure 3) were estimated using the distributed cattle density and *E. coli* production rate.

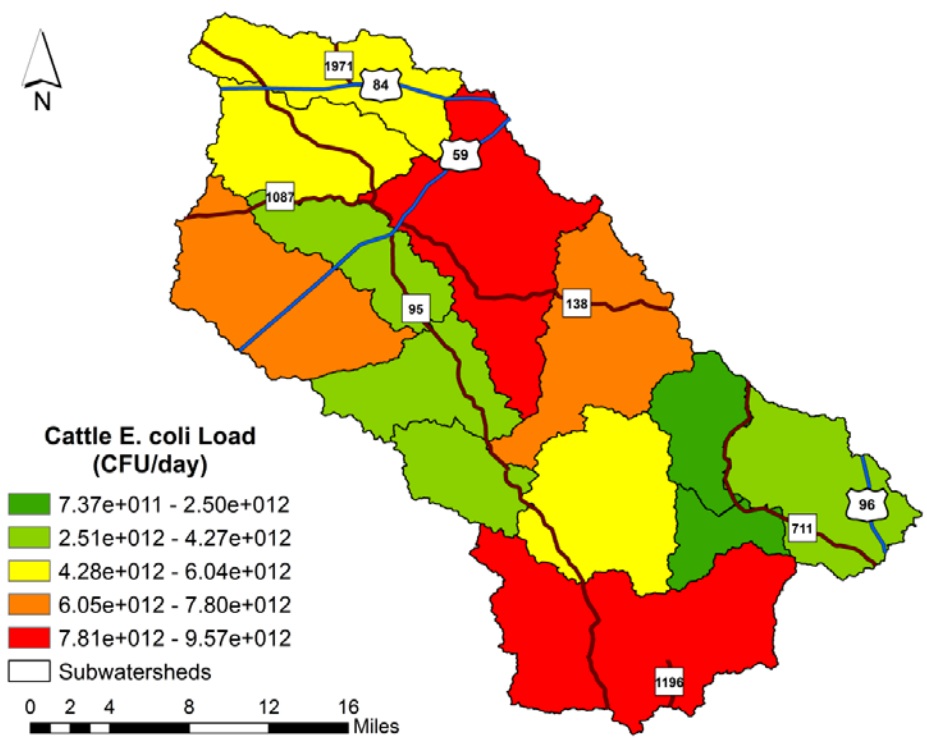


Figure 3. Potential *E. coli* load resulting from Cattle for the Attoyac Bayou Watershed.

1.2.2. Livestock – Horses

A total of 587 horses were evenly distributed over rangeland, managed pasture, and developed, open spaces. This number was derived by averaging the number of horses in the watershed as indicated by stakeholder surveys. These numbers are slightly lower than estimates from the USDA NASS. The *E. coli* production rate used in the model was 1.08 x 10^8 CFU per animal per day and was calculated using a fecal coliform density of 1.26 x 10^4 CFU per gram, a fecal production of 30 pounds per animal unit per day, and a fecal coliform to *E. coli* conversion of 0.63. Each of these numbers and the land use land cover classes to apply this source to was selected by watershed stakeholders and the project team. The total potential *E. coli* loads for horses (Figure 4) were estimated using the distributed horse density and *E. coli* production rate.

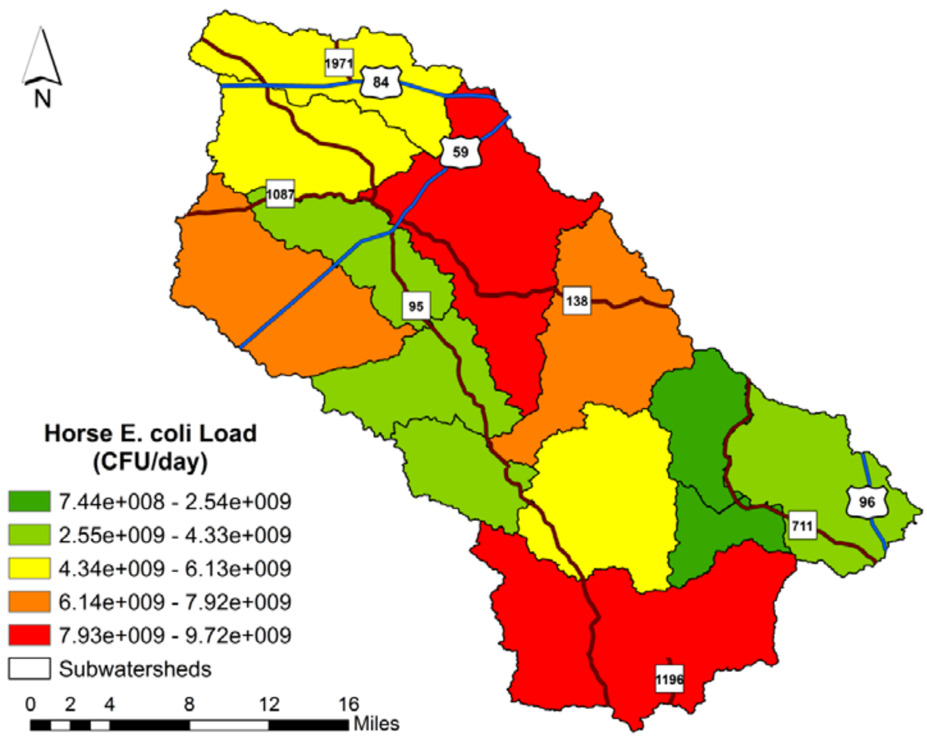


Figure 4. Potential *E. coli* load resulting from Horses for the Attoyac Bayou Watershed.

1.2.3. Wildlife - Deer

A total of 7,547 deer were applied over contiguous areas of barren land, forested land, pine plantation, mixed forest, near riparian forest, rangeland, managed pasture, and cultivated crops in the watershed. This is the population estimate produced by applying the Texas Parks and Wildlife Department-derived deer density for the resource management unit that the Attoyac Bayou watershed lies within. Watershed stakeholders felt this was the most appropriate estimate. The *E. coli* production rate used was 9.43×10^9 CFU per animal per day and was calculated using a fecal coliform density of 2.20×10^6 CFU per gram, a fecal production of 15 pounds per animal unit per day, and a fecal coliform to *E. coli* conversion of 0.63. Each of these numbers and the land use land cover classes to apply this source to were selected by watershed stakeholders and the project team. The total potential *E. coli* loads for deer (Figure 5) were estimated using the distributed deer density and *E. coli* production rate.

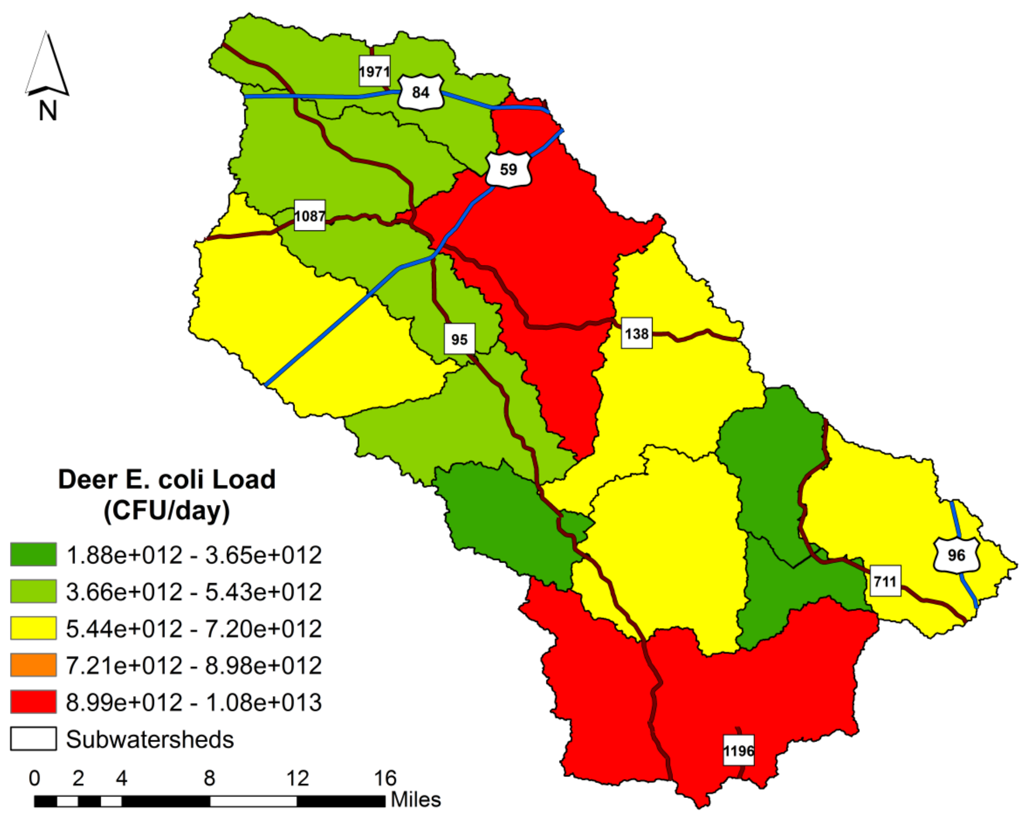


Figure 5. Potential *E. coli* Load resulting from Deer for the Attoyac Bayou Watershed.

1.2.4. Feral Hogs

A total of 10,155 feral hogs were applied uniformly across barren land, forested land, pine plantation, mixed forest, near riparian forest, rangeland, managed pasture, and cultivated crops within a 100 foot buffer around the stream network of the watershed. This population estimate was derived by averaging stakeholder survey responses and is quite similar to applying the hog density recommended by Wagner and Moench (2009) for the Copano Bay watershed near Corpus Christi, TX. The *E. coli* production rate used was 1.16×10^9 CFU per animal per day and was calculated using a fecal coliform density of 4.05×10^5 CFU per gram, a fecal production of 10 pounds per animal unit per day, and a fecal coliform to *E. coli* conversion of 0.63. Each of these numbers and the land use land cover classes to apply this source to was selected by watershed stakeholders and the project team. The total potential *E. coli* loads for feral hogs (Figure 6) were estimated using the distributed feral hog density and *E. coli* production rate.

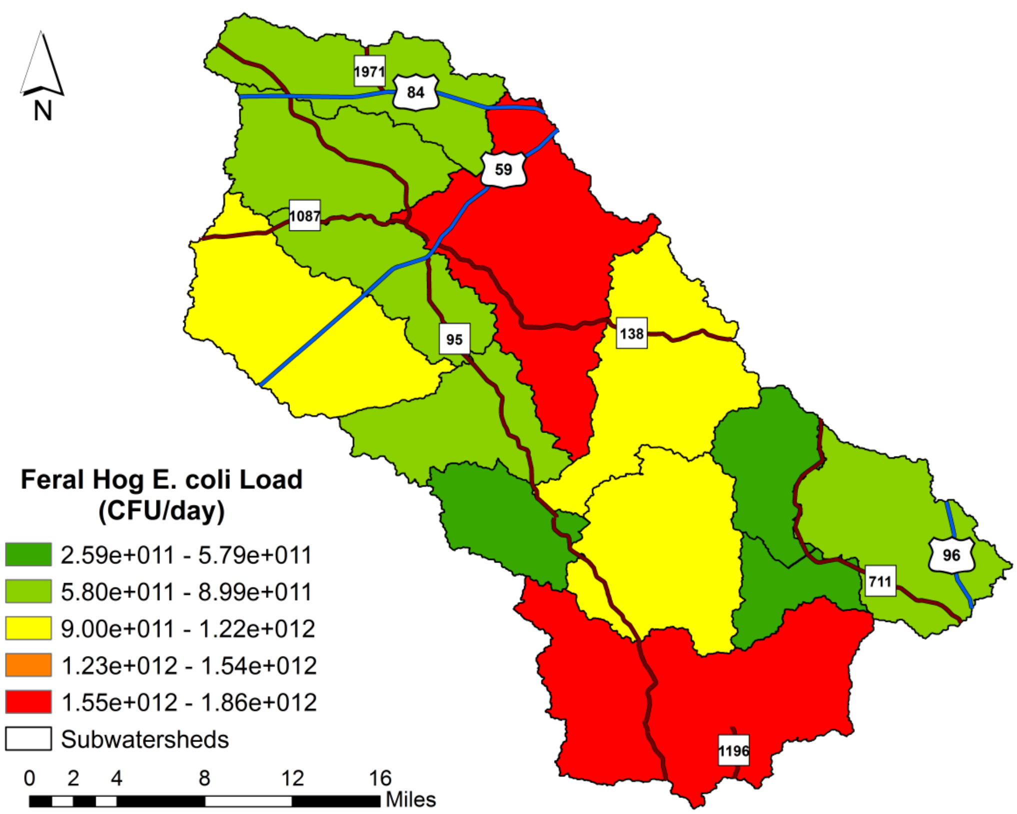


Figure 6. Potential *E. coli* Load resulting from Feral Hogs for the Attoyac Bayou Watershed.

1.2.5. Poultry Litter

The poultry litter contribution in the watershed was modeled by evenly distributing 63,440 tons of litter over areas where poultry litter has likely been applied. The quantity of litter applied is derived from litter production figures maintained by the Texas State Soil and Water Conservation Board (TSSWCB). Stakeholders estimated that of the litter produced in the watershed, two-thirds was land applied in the watershed. To determine the most appropriate locations to apply poultry litter in the watershed, Stephen F. Austin State University personnel provided results from a multi-spectral, infrared imagery analysis conducted that illustrates which fields in the watershed receive nutrient amendments. Stakeholders agreed that this approach illustrates the most likely areas where poultry litter is applied. The poultry litter *E. coli* load (Figure 7) was calculated using the litter distribution and an *E. coli* density of 100 CFU per gram of litter. This low level was chosen by stakeholders due to the inability to produce live *E. coli* from desiccated litter that is applied in the watershed.

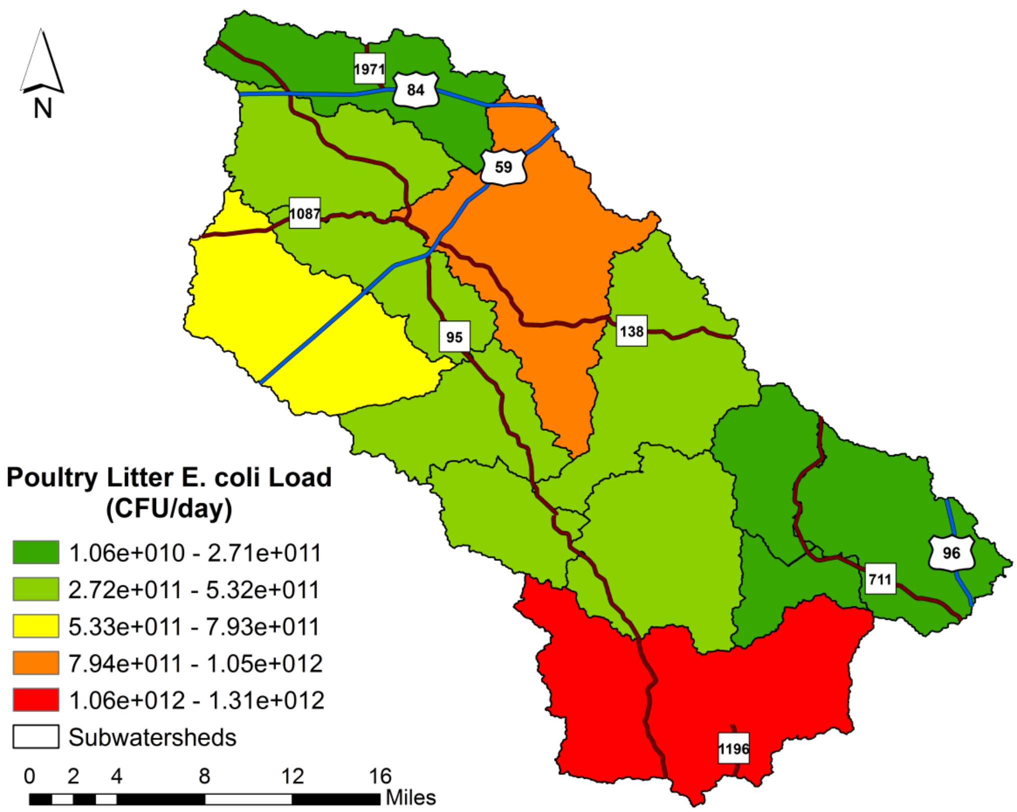


Figure 7. Potential *E. coli* Load resulting from Poultry Litter for the Attoyac Bayou Watershed.

1.2.6. Septic Systems

Septic systems were modeled using spatially distributed point data of each household obtained from residential 911 address data gathered from the Deep East Texas and East Texas Councils of Government. Households within Certificate of Convenience and Necessity (CCN) areas were removed to exclude households being serviced by a WWTF. Additionally, a portion of the 911 address data included information on the type of structure at that address. Using the percentage of structures assumed to not have a septic system (barns, shops, other), the total number of structures with septic systems in the watershed was scaled down to 6,085. 2010 Census data indicated an average of 2.12 persons per household for the Attoyac Bayou watershed. An *E. coli* concentration of raw sewage (1.65×10^{10} CFU per person per day) was used to model failing OSSFs as they are considered to provide little if any wastewater treatment. The appropriate OSSF failure rate as determined by watershed stakeholders was 50%. This was used to calculate the percentage of *E. coli* contributing to the watershed due to OSSF failures (Figure 8).

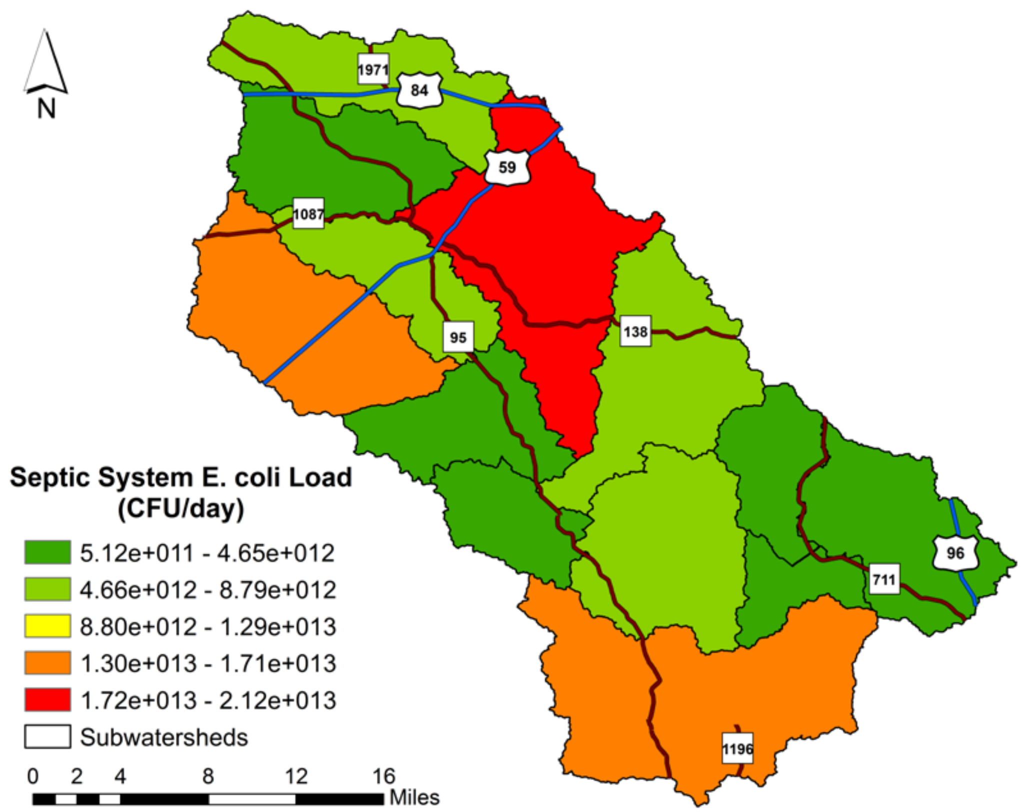


Figure 8. Potential *E. coli* load resulting from Septic Systems for the Attoyac Bayou Watershed.

1.2.7. Dogs

A dog density of 1.7 dogs per household was determined by the stakeholders. This is the national dog density as reported by the American Veterinarian Medical Association and watershed stakeholders agreed that it was most appropriate for the watershed. The density was applied to the residential 911 addresses, resulting in an estimated dog population of 11,285. The *E. coli* production rate of 3.15 x 10^9 CFU per dog per day was used to determine the potential *E. coli* load resulting from dogs (Figure 9). Watershed stakeholders and the project team concurred that this information appropriately represents conditions in the Attoyac Bayou watershed.

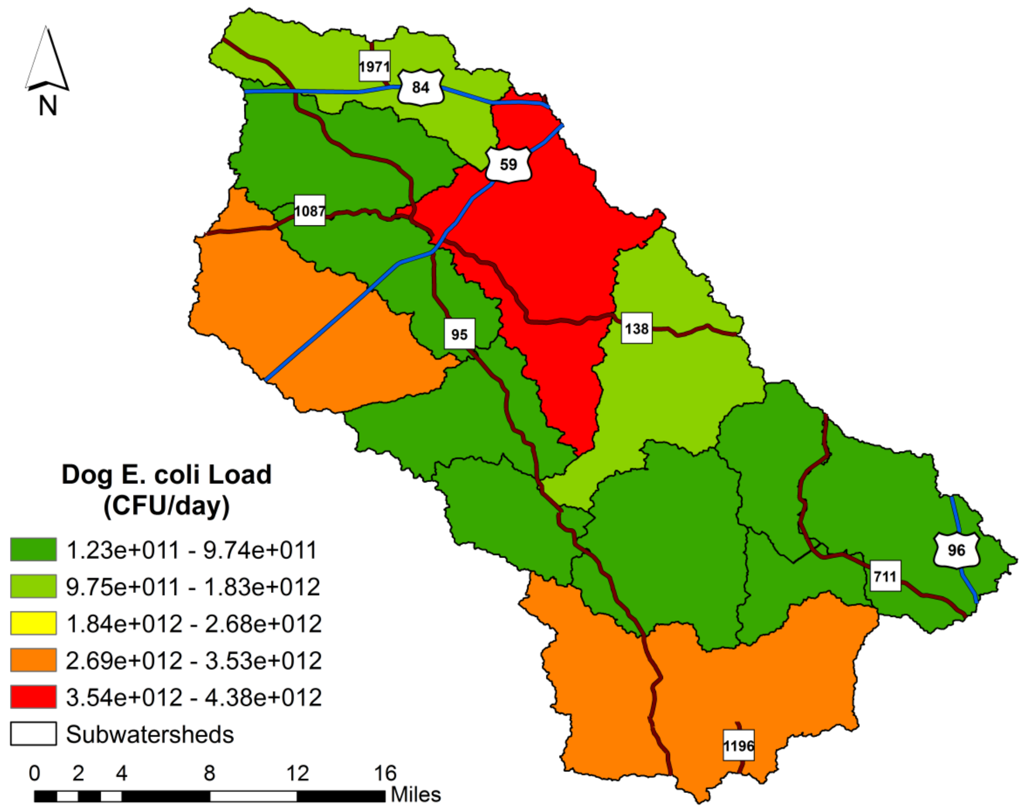


Figure 9. Potential *E. coli* Load resulting from Dogs for the Attoyac Bayou Watershed.

1.2.8. WWTFs

There are three WWTFs in the Attoyac Bayou watershed: Chireno ISD, City of Garrison, and Martinsville ISD with permitted discharges of 10,000, 120,000, and 8,000 gallons per day respectively. Realizing that these are maximum permitted discharges, each WWTF was modeled at half of its permitted discharge. An *E. coli* concentration of 25 CFU per 100 milliliters was used to model the potential impacts of WWTFs as monitoring data indicate that average *E. coli* levels observed in WWTF effluent are quite low. Watershed stakeholders and the project team concurred that this information appropriately represents conditions in the Attoyac Bayou watershed and it was utilized to produce the expected *E. coli* loads seen in Figure 10.

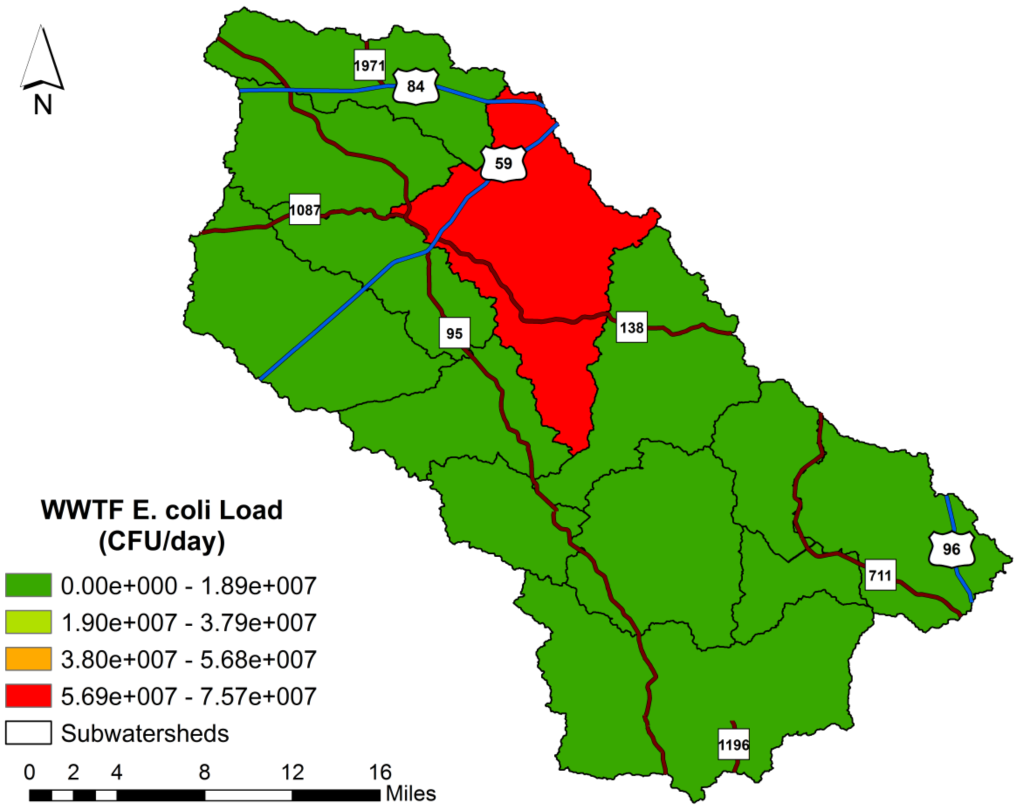


Figure 10. Potential *E. coli* Load resulting from WWTFs for the Attoyac Bayou Watershed.

1.2.9. Hunting Camps

Based on stakeholder surveys, a total of 125 hunting camps were estimated in the watershed and were considered to be distributed evenly over forested land, pine plantation, mixed forest, and near riparian forest. The hunting camp distribution and the *E. coli* concentration rate of raw sewage 1.65 x 10^{10} CFU per person per day were used to calculate the hunting camp *E. coli* load (Figure 11).

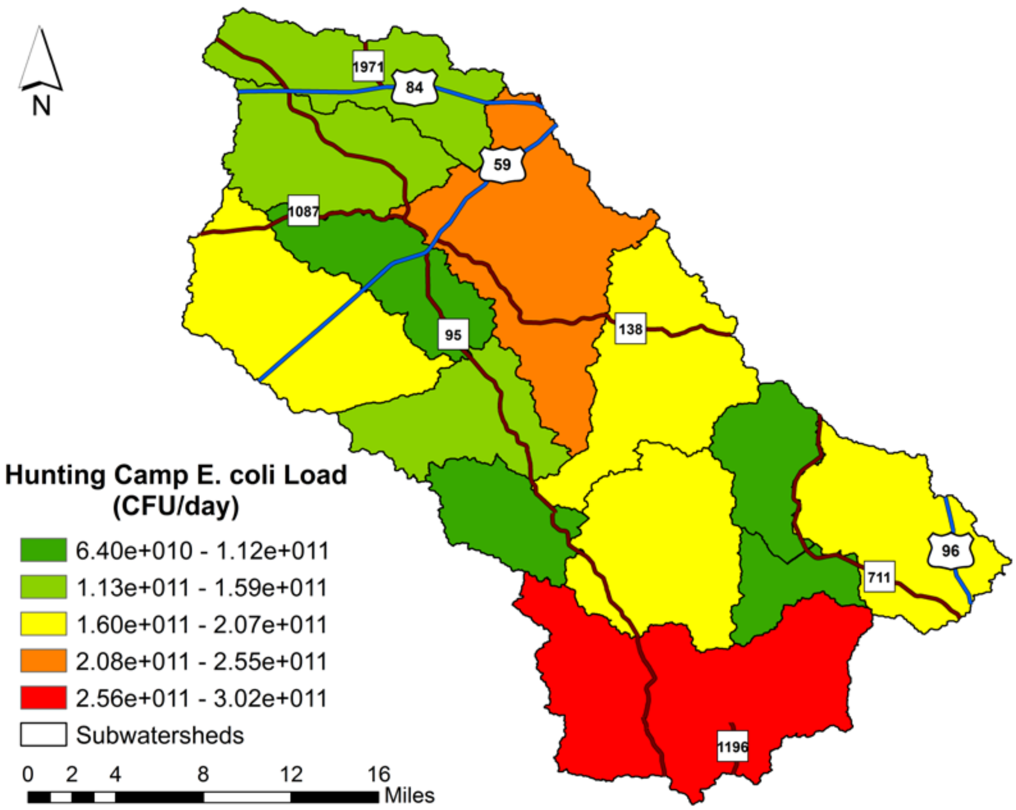


Figure 21. Potential *E. coli* Load resulting from Hunting Camps for the Attoyac Bayou Watershed.

1.3. SELECT Analysis Results

Combining the potential *E. coli* loading estimates of all modeled sources yielded a total daily potential *E. coli* load range for the watershed of 7.68×10^{13} to 2.74×10^{15} CFU per day (Figure 12). Potential loads are also aggregated at the sub-watershed level thus indicating which sub-watershed has the highest potential for *E. coli* loading to the watershed.

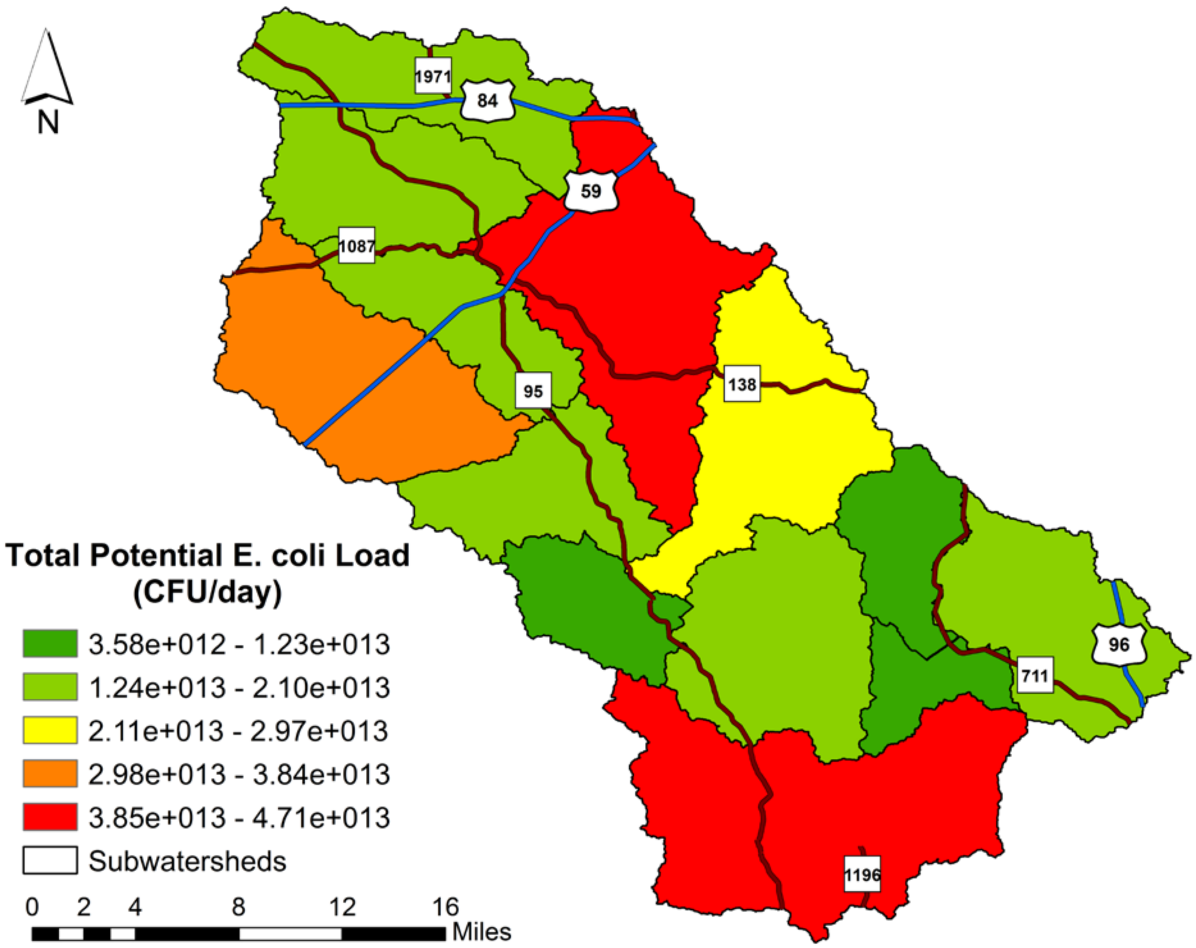


Figure 12. Daily Total Potential *E. coli* Load for the Attoyac Watershed.

The contributor with the highest daily potential *E. coli* load in the watershed was septic systems while hunting camps and deer where the next highest contributors. Sources with potential contributions in the middle of the range were cattle, feral hogs, dogs and poultry litter. The lowest contributors were horses and WWTFs. Figures 13 and Table 2 illustrate these relative ranges of potential pollution contribution of each modeled source.

Table 2. Daily Potential *E. coli* Load Ranges per Source.

Potential *E. coli* Sources	**Daily Potential *E. coli* Load (CFU/day)**
Cattle	$7.37 \times 10^{11} - 9.57 \times 10^{12}$
Horses	$7.44 \times 10^{8} - 9.72 \times 10^{9}$
Deer	$1.88 \times 10^{12} - 1.08 \times 10^{13}$
Feral Hogs	$2.59 \times 10^{11} - 1.86 \times 10^{12}$
Poultry Litter	$1.06 \times 10^{10} - 1.31 \times 10^{12}$
OSSFs	$5.12 \times 10^{11} - 2.12 \times 10^{13}$
Dogs	$1.23 \times 10^{11} - 4.38 \times 10^{12}$
WWTFs	$0 - 7.57 \times 10^{7}$
Hunting Camps	$6.40 \times 10^{10} - 3.02 \times 10^{11}$

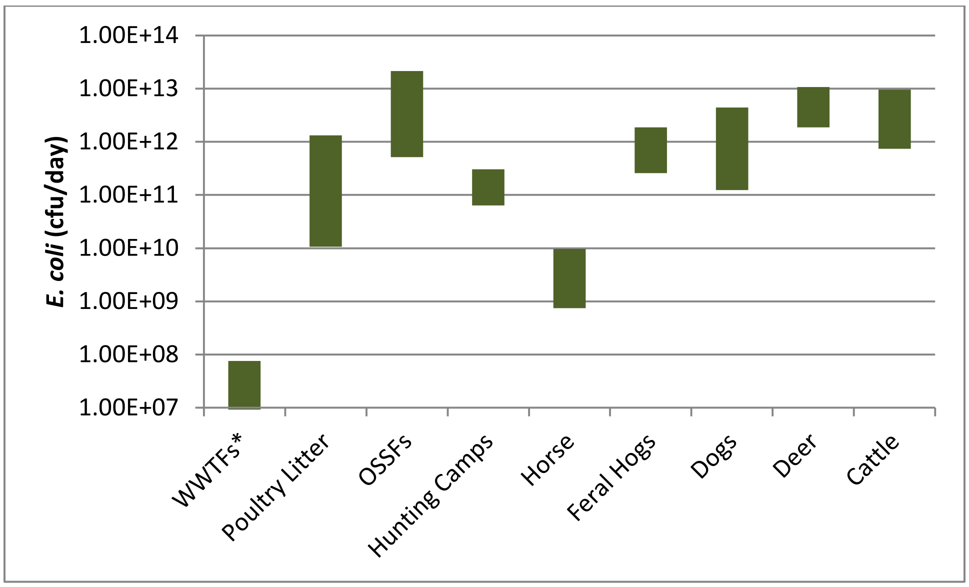


Figure 13. Relative Potential Loading Ranges Across Attoyac Bayou Subwatersheds by Source. (* note that the lower boundary for the WWTF loading range is actually 0 cfu/day)

2. SUMMARY

Daily potential *E. coli* sources resulting from various sources were estimated using a spatially explicit load estimation tool.

1. The highest potential *E. coli* contributor in the watershed was OSSFs followed by hunting camps. The *E. coli* concentration of raw sewage is much higher than the other *E. coli* production rates for the other potential sources thus yielding this result.

2. Deer were found to contribute similarly to hunting camps. This is likely because the *E. coli* concentration for deer was higher by almost a factor of 10 compared to the other animal contributors.
3. Cattle, feral hogs, poultry litter, and dogs were medium contributors. The *E. coli* production rate was similar for cattle, feral hogs, and dogs, which is why they have a similar potential *E. coli* load.
4. The lowest contributors were horses and WWTFs. The horse population was much lower compared to the other animal sources and the *E. coli* production rate was lower as well, which is why horses were a low contributor.

3. REFERENCES

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