Section 3

# Identifying Pollutant Sources

Photo Credit: Kendall Guidroz

# Section 3. Identifying Pollutant Sources

The process of identifying, characterizing, and quantifying causes and sources of pollution in a watershed provides a rational basis for devising effective solutions to improve water quality. The Partnership used a variety of tools, combined with local knowledge and guidance, to investigate the water quality challenges facing the East Fork San Jacinto River watershed. The purpose of these efforts is to provide local stakeholders the information and context to make informed and effective decisions for their communities.

## Investigation Methodology

The process of investigating causes and sources of pollution in the watershed used a series of successive steps to bridge the gap between the known existence of impairments and concerns, and the calculation of defensible estimations of causes and sources of pollution to meet the needs of the stakeholders[20].

### Water Quality Goals

The applicability of each step to different pollutants/conditions of concern is based on the water quality goals established by the stakeholders (see Section 1) and is noted in parentheses for each step.

- **Water quality data analysis (all water quality issues)** — Project staff identified status and trends in ambient water quality monitoring data and discharge data from wastewater treatment plants. These analyses identify the extent and variability of water quality issues and highlight differences between areas in the watershed.
- **Source identification and feedback (all water quality issues)** — The Partnership used local knowledge, data from other efforts, field reconnaissance, and map analysis to identify potential sources. These steps help to shape subsequent analyses by focusing efforts on sources of priority in the watershed.
- **Source load modeling (fecal waste)** — H-GAC worked with the Partnership to estimate the potential amount of fecal waste/*E. coli* generated in the watershed using computer models guided by local knowledge and feedback. These efforts identified the potential total fecal loads, mix of sources responsible, and variation between different areas of the watershed.
- **Reduction/Improvement modeling (fecal waste, DO)** — H-GAC worked with the Partnership to estimate the amount of improvement needed to meet water quality standards for various areas in the waterway. Results were generated by computer

[20] More detailed information on the development of this investigation methodology and selection of models can be found in the Bacteria Modeling Report, located at: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_4.3_bacteria_modeling_report_final.pdf

models using then-current water quality monitoring data. These processes generated the percent reduction for *E. coli* levels (see Section 4).

- **Source and improvement linkage (fecal waste)** — As the primary focus and sole impairment in the watershed, fecal indicator bacteria estimates were needed to establish numeric reduction goals for *E. coli*. This process applied the percent reduction targets from the improvement modeling to *E. coli* source load estimations to generate the amount of source load that needed to be reduced to achieve the water quality standard (see Section 4).
- **Coordinate with partner efforts (other concerns)** — Most specifically in the case of flood mitigation, the primary focus of developing recommendations for concerns outside the scope of this WPP was coordinating with partners.
- **Emphasize human wastewater as a priority** – While models may downplay the contribution of human wastewater, the stakeholders emphasized the greater risk human waste carries, the greater likelihood it is to be in proximity to our communities, and the potential for acute overflow events that do not reflect average daily loads.

## Water Quality Analysis

Assessing water quality data sources is the first step in narrowing the search for the causes and sources of pollution. The Partnership reviewed analyses of 1) ambient water monitoring data, 2) volunteer water quality monitoring data, and 3) discharge monitoring reports (DMRs) and sanitary sewer overflow (SSO) data from wastewater treatment facilities. While these analyses are summarized here, greater detail on the methods and results can be found in the *Water Quality Data Analysis Summary Report*[21] prepared for this WPP. The primary goals of the analyses were to better understand water quality conditions, characterize the quality of wastewater contributions, and identify the availability of sufficient data for the models. The analyses focused on a five-year period of data to represent the most current conditions, but also relevant trends in recent years.

### Ambient Water Quality Monitoring Data

Ambient water quality data are collected at over 400 sites in the 13-county Houston-Galveston region by H-GAC, local partners, and TCEQ as part of the Clean Rivers Program[22]. Most monitoring stations are sampled by CRP partners[23]. Waterways are

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[21] Available on the project website at: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_3.2_acquired_data_analysis_report_final.pdf

[22] More information about this state-wide water quality monitoring program can be found at: https://www.tceq.texas.gov/waterquality/clean-rivers

[23] More information about the specific monitoring and programmatic details of the local CRP can be found at: https://www.h-gac.com/clean-rivers-program/information/

inherently dynamic systems, and water quality at any given time can vary greatly dependent on conditions at the time. However, a history of ambient water quality samples helps characterize the range of conditions that may be present in a waterway and is important for the identification of trends over time. The final determination of the regulatory status of each segment is based primarily on these ambient data. Goals and decisions for this WPP were established in part due to the regulatory status, and therefore ambient data is an important source of information for informing stakeholder decisions.

The East Fork San Jacinto River system is heavily monitored, with 14 active monitoring stations: seven on the main body, five on Winters Bayou (1003A), one on Nebletts Creek (1003B), and one on Boswell Creek (1003C; **Figure 10**; **Table 6**).

**Table 6.** CRP monitoring station locations in the East Fork San Jacinto River watershed

| Station | Stream Segment | Assessment Unit |
|---|---|---|
| 11235 | East Fork San Jacinto River | 1003_01 |
| 11236 | East Fork San Jacinto River | 1003_01 |
| 11237 | East Fork San Jacinto River | 1003_02 |
| 11238 | East Fork San Jacinto River | 1003_02 |
| 14242 | East Fork San Jacinto River | 1003_02 |
| 21939 | East Fork San Jacinto River | 1003_02 |
| 17431 | East Fork San Jacinto River | 1003_03 |
| 21417 | Winters Bayou | 1003A_01 |
| 21933 | Winters Bayou | 1003A_01 |
| 21935 | Winters Bayou | 1003A_01 |
| 21936 | Winters Bayou | 1003A_01 |
| 21937 | Winters Bayou | 1003A_01 |
| 21938 | Nebletts Creek | 1003B_01 |
| 21934 | Boswell Creek | 1003C_01 |

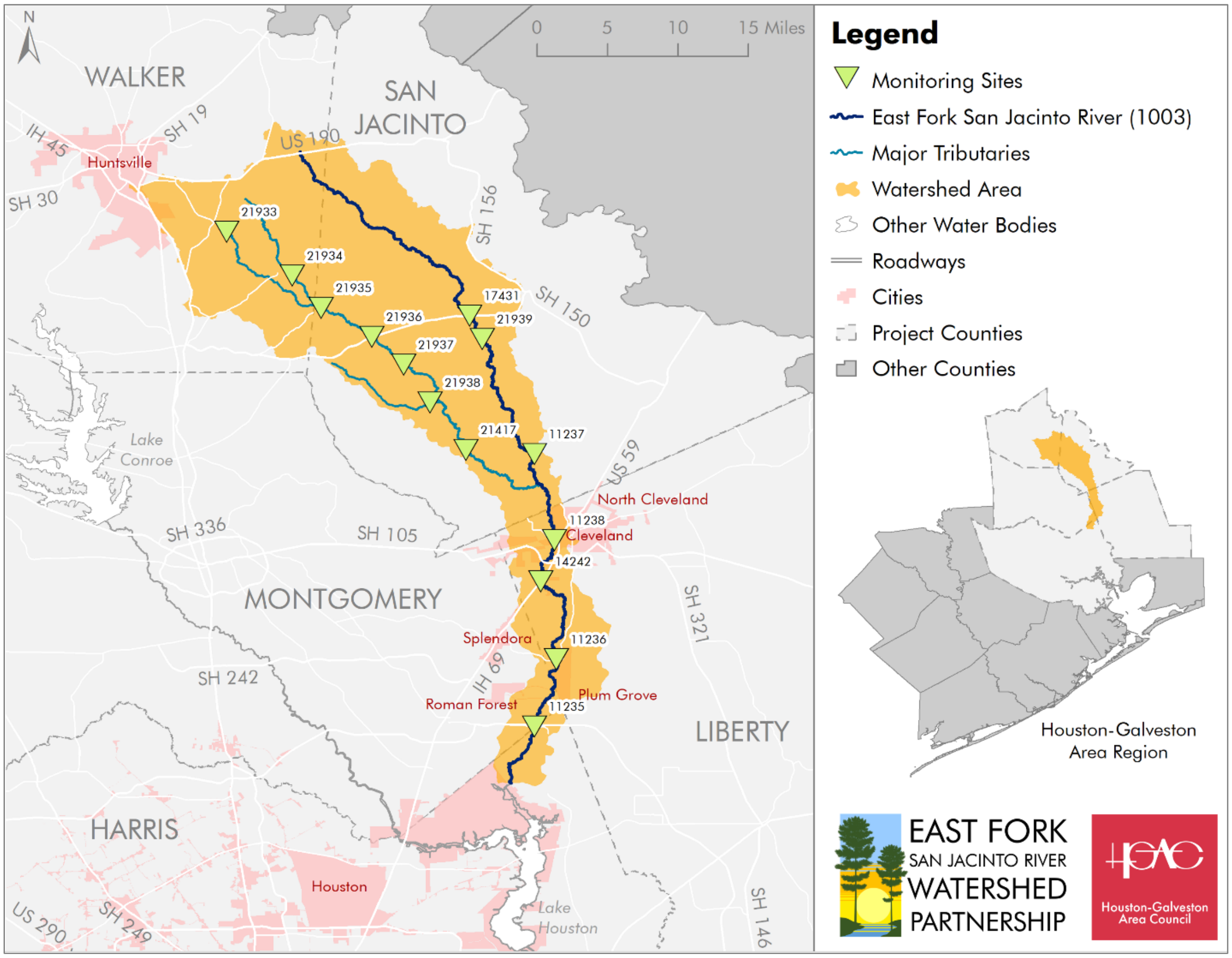


Figure 10. East Fork San Jacinto River watershed monitoring stations

## Constituents of Concern

Routine ambient water quality monitoring under the CRP includes sampling for a suite of conventional, bacteriological, and field parameters. For this evaluation, a subset of those parameters most closely related to the goals of the WPP and characterization studies has been selected for in-depth analysis. The parameters reviewed were:

- *E. coli* — a bacterial indicator of the presence of fecal wastes, and an indicator of the safety of waterways for human recreation.
- **DO (grab)** — an indicator of the ability of the waterway to support aquatic life.
- **Temperature** — an indicator of a waterway's ability to hold oxygen, and a means for correlating other indicators to conditions in the waterways.
- **pH** — an indicator of the acidity or alkalinity of water, which may affect aquatic life and other uses.

- **Chlorophyll-*a* (Chl-*a*)** — an indicator of aquatic plant productivity and action, which can indicate areas in which algal blooms or elevated nutrient levels are present, and thus potentially depressed DO.
- **Nitrate ($NO_3$-N) and Nitrite ($NO_2$-N)** — a measure of nitrogenous compounds and indicator of nutrient levels (and thus potential DO impacts).
- **Ammonia Nitrogen ($NH_3$-N)** — a measure of specific nitrogenous compound that can impact aquatic life and is an indicator of nutrient levels and potentially of improperly treated sewage effluent.
- **Total Phosphorus (TP)** — an indicator of nutrient levels, especially in relation to potential for algal blooms and depressed DO in elevated levels.
- **Total Suspended Solids (TSS)** — a measure of the number of suspended particles in water that indicates the potential of light infiltration in the water column and the presence of particulate matter which *E. coli* may use as substrate.

The analyzed data covers 2011to 2021 to show a broad historic view. The primary questions this evaluation sought to answer relate to:

- The sufficiency of the data to characterize conditions,
- The spatial component of variations in water quality conditions,
- The extent of water quality issues, and
- Trends in water quality conditions, including any observable seasonal patterns.

H-GAC completed the assessment on the segment level, with attention to any unclassified tributaries which may be experiencing water quality issues.

### Monitoring Analysis

A summary of ambient data represented as the geomean of each parameter for its period of record (2011 to 2021) is shown in **Table 7** below. This dataset is from TCEQ's Surface Water Quality Monitoring Information System and the period of record is designed to match that of the load duration curves mentioned in Section 4. These results are not directly comparable to that of the 2022 Texas Integrated Report which uses a different period of record (2013 to 2020) and assessment methodology for determination of Texas Surface Water Quality Standards attainment.

Table 7. Water quality monitoring geometric mean results by segment, 2011 to 2021

| Parameter | Criteria | Unit | East Fork San Jacinto River, 1003 | Winters Bayou, 1003A | Nebletts Creek, 1003B | Boswell Creek, 1003C |
|---|---|---|---|---|---|---|
| Temperature | NA | °C | *18.5* | *18.2* | *18.5* | *17.1* |
| DO, grab | Various | mg/L | 7.2 | 6.3 | 8.6 | 6.9 |
| pH | 9 (high) 6.5(low) | NA | 7.1 | 7.2 | 6.5 | 7.1 |
| TSS | NA | mg/L | *16.9* | *13.5* | *5.1* | *36. 7* |
| Total Phosphorus | 0.69 | mg/L | 0.1 | 0.1 | 0.1 | 0.1 |
| Nitrate | 1.95 | mg/L | 0.1 | 0.1 | 0.1 | 0.1 |
| Nitrite | NA | mg/L | *0.1* | *0.1* | *0.1* | *0.1* |
| Nitrate and Nitrite | NA | mg/L | *0.1* | *0.1* | *No Data* | *No Data* |
| Ammonia Nitrogen | 0.33 | mg/L | 0.1 | 0.1 | 0.1 | 0.2 |
| *E. coli* | 126 | cfu/100mL | 199.0 | 172.9 | 103.6 | 182.4 |

**Note:** Results shaded in dark gray indicate geomeans that exceed criteria or screening levels, while those shaded in light gray represent results that comply with criteria or screening levels. Italicized values indicate the data is not being compared to criteria or screening levels. This trend analysis does not reflect analysis or conclusions from the Texas Integrated Report.

### Water Quality Parameter Trends

By examining all parameters collected from surface water samples in the East Fork San Jacinto River watershed and how measurements for those parameters have changed over time, statistically significant ($p < 0.0545$) trends in the data were determined. Of the ambient water quality parameters observed, geometric mean values for fecal indicator bacteria levels measured between 2011 and 2021 exceeded surface water quality standards in segments 1003, 1003A, and 1003C. No significant trends in *E. coli* over time were observed in any of the segments. Geometric means for nutrients such as total phosphorous, nitrate, nitrite, and ammonia nitrogen met the criteria in all segments. Though the trend analyses for nutrients generally did not yield significant results, nitrate measurements on segment 1003 and 1003A were observed to decrease significantly over time.

### Relationship to Flow

Parameter measurements and their relationships to flow conditions were considered in this analysis. Further work on the relationship between flow and bacteria was completed as part of the model development explained in Section 4. According to the results of the models, surface water in the East Fork San Jacinto River watershed is likely impacted by nonpoint source pollution. This is indicated by fecal indicator bacteria concentrations that are observed to increase with flow magnitude.

**Ambient Data Analysis Summary**

Of the ambient water quality parameters observed, geomean values for fecal indicator bacteria levels measured between 2011 and 2021 exceeded state water quality standards. Only Nebletts Creek (1003B) showed geomean values for *E. coli* within criteria levels. Unlike other water bodies in the Houston-Galveston Area region, nutrients do not seem to pose a challenge to water quality in the East Fork San Jacinto River Watershed. Likewise, levels of DO are well above the level of concern in all segments. Targeted assessment and application of best management practices could be expected to reduce or remove impairments and concerns in this watershed.

### Stream Team Monitoring

While the WPP relies on quality assured data for trends analyses and model inputs, volunteer data provided by local Texas Stream Team (TST) monitors can be a valuable supplement to routine monitoring sites by providing hints at conditions in areas outside the existing data. One of the most valuable elements of TST data is the observational information from the volunteers. While there are currently no active TST sites in the East Fork San Jacinto River watershed, stakeholders have expressed interest in establishing a TST site to help identify WPP effectiveness going forward.

### Wastewater Treatment Facility Discharge Data

Discharges from wastewater treatment facilities (WWTFs) are regulated by Texas Pollutant Discharge Elimination System (TPDES) permits from TCEQ which require stringent limits for effluent quality. Human waste can cause human illness, so identifying trends in permit exceedances for *E. coli* by WWTFs is important in understanding overall impacts to human health related to contaminated waterways. Additionally, effluent (especially if improperly treated) can be a source of nutrient or other precursors to depressed DO. At the time of this study, there are 10 permitted WWTFs with 11 outfalls in the East Fork San Jacinto River Watershed (**Figure 11**; **Appendix B**. Wastewater Treatment Facilities).

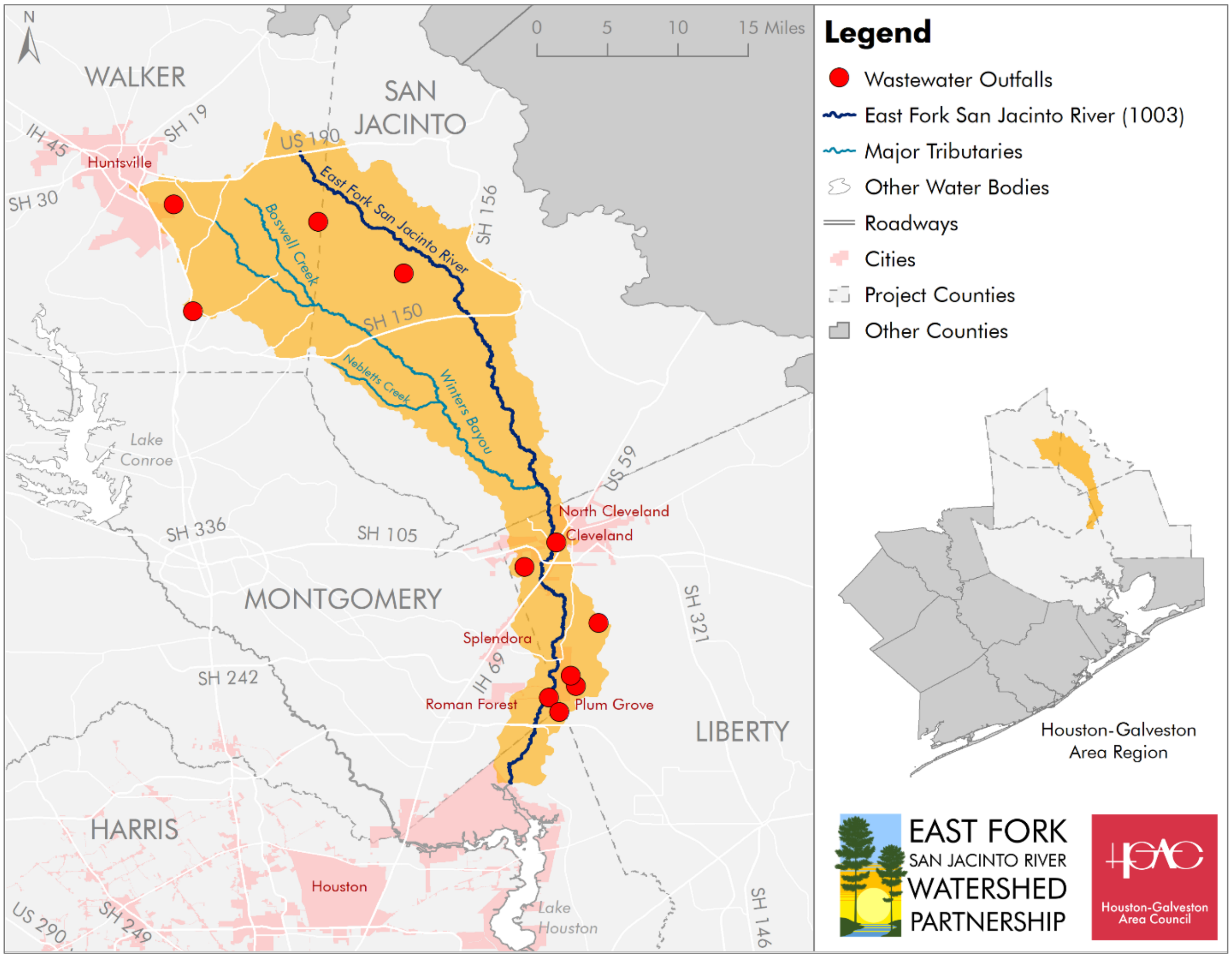


Figure 11. WWTF outfalls in the East Fork San Jacinto River watershed

Discharges from WWTFs are monitored on a regular basis (with a frequency dependent on facility size and other factors). The data from these required sampling events are submitted to (and compiled by) TCEQ as DMRs. As with any self-reported data, there is an expectation that some degree of uncertainty or variation from conditions may occur, but these DMRs are the most comprehensive data available for evaluating WWTFs in the watershed.

Project staff evaluated[24] DMRs from TCEQ reported between 2017 and 2021 by WWTF permit holders in the East Fork San Jacinto River watershed. Five parameters common to most WWTF permits were assessed including: *E. coli*, TSS, ammonia nitrogen ($NH_3$-N), DO, and five-day carbonaceous biochemical oxygen demand ($CBOD_5$). While some parameters are themselves constituents of concern, all are indicators of the presence or

[24] For more detail, see the Water Quality Data Analysis Summary Report on the project website at: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_3.2_acquired_data_analysis_report_final.pdf

potential presence of untreated/improperly treated waste[25]. The parameter evaluations were based on the regulatory permit limits specific to each facility, and consider the number of exceedances by each facility, in each year, in each segment, and as a percentage of the total samples.

***E. coli***

Effluent discharge from WWTFs is assessed for compliance with the TPDES permitted limits. For this analysis, DMR data were compared to TPDES permit limits for bacteria across segments, facility types, years, and seasons. The values for exceedances of geomean and single sample limits in **Table 8** were calculated for each facility depending on their specific permit limits. Several facilities in the watershed have more stringent bacteria limits than SWQS (e.g., 63 cfu/100mL) as required in a TMDL. However, when the WWTF bacteria loading was estimated in the SELECT process, an assumed effluent concentration of 126 cfu/100 mL was used for all facilities to get a high-end estimate for loading that the stakeholders felt was more appropriate. Exceedance statistics are summarized in **Table 8**.

**Table 8.** DMR bacteria exceedance statistics, 2017 to 2021

| Parameter | Number of Facilities | Percent of Facilities | Percent of Reports |
|---|---|---|---|
| Facilities in DMR Dataset | 10 | | |
| Facilities Reporting Bacteria | 8 | | |
| Total Records | 217 | | |
| Less than 1% Violations | 6 | 75.0% | |
| 1% to 5% Violations | 2 | 25.0% | |
| 5% to 10% Violations | 0 | 0.0% | |
| 10% to 25% Violations | 0 | 0.0% | |
| Greater than 25% Violations | 0 | 0.0% | |
| Exceedances of Geomean | 1 | | 0.4% |
| Exceedances of Single Grab | 1 | | 0.4% |
| Total Exceedances | 2 | | 0.9% |

**Note:** Several facilities in the watershed have more stringent permit limits (e.g., 63 cfu/100mL) required in a TMDL. For DMR analyses, the actual permit limit for each facility was used.

Overall, the results of the analyses of DMR *E. coli* data indicated that the total number of exceedances reported was small relative to the total number of DMR reports submitted for the period of 2017 to 2021 (2 out of 217 records). Maximum

[25] In consideration of the nutrient loading capacity of the facilities, it should be noted that many nutrient parameters are not standard facility permit limits, and thus may not be tested. Based on review of correlations between nutrient parameters and flow for many stations, the analyses did show a likelihood of facilities as nutrient loading sources for non-permit limit parameters, particularly in effluent-dominated streams.

single grab values and geomean limits were each exceeded only once. Seasonality was not observed to be significant in shaping trends in bacteria concentrations. Plant age and size are also not believed to correlate in any way with the observed exceedances. While WWTFs may be appreciable contributions under certain conditions and in localized areas, the DMR analysis indicates that they are not likely a significant driver of segment bacteria impairments due to the comparatively few exceedances. However, due to the relatively higher risk of pathogens from human waste, and proximity to developed areas, WWTF exceedances are still a point of concern for stakeholders.

**Dissolved Oxygen**

DO levels in WWTF effluent help indicate the efficiency of treatment processes. DO is generally more stable in effluent than it can be in ambient conditions because it is less subject to natural processes and variation in insolation. DO is measured in milligrams per liter (mg/L), and the permit limits can vary based on the receiving water body and other factors. Unlike other contaminants, DO limits are based on a minimum, rather than maximum level, and represent a grab sample as opposed to a 24-hour monitoring event. Generally, permit limits for the data reviewed ranged between 4-6 mg/L. Evaluations for compliance with the permit limits were for all records, between years, and by season. Nine plants reported DO results during this period. The outcomes are summarized in **Table 9** below.

Table 9. DMR DO exceedance statistics, 2017 to 2021

| Parameter | Number | Percent of Records |
|---|---|---|
| Facilities in DMR Dataset | 10 | |
| Facilities Reporting DO | 9 | |
| Total Records | 367 | |
| Total Exceedances | 1 | 0.27% |

Only one sample of 367 total reports fell below the minimum standard. After arranging the data temporally, no annual or seasonal trends were observed in the reported data. However, it is important to note that periodic impacts to DO levels may occur on a localized level but may not be well represented in this broad analysis. While the impacts of WWTFs on DO levels may not be a chronic or widespread issue in the watershed, an analysis of DO values reported in DMRs is still a critical component of this project especially as it pertains to identifying localized impacts.

### Total Suspended Solids

To determine the efficiency of wastewater treatment in removing solids, TSS is evaluated. Bacteria use suspended particles as a protected growth medium and can therefore occur in greater concentrations when TSS is high. Additionally, TSS can be useful as an indicator that inefficient treatment may have led to other waste products (nutrients, *etc.*) being elevated in effluent. Permit limits for TSS include a concentration based (average) limit in mg/L and a total weight-based limit in pounds per day. Both average and maximum monitored results exist for most facilities. Evaluations for compliance with concentration and total weight permit limits were made for the overall dataset and for annual and seasonal data. The summary of reports made for TSS measurements, and the number of exceedances of the concentration and weight limits are presented in **Table 10** below.

**Table 10.** DMR TSS exceedance statistics, 2017 to 2021

| Category | Number | Percent of Records |
|---|---|---|
| Facilities in DMR Dataset | 10 | |
| Facilities Reporting TSS | 9 | |
| Total Records | 367 | |
| Exceedances of Concentration | 23 | 6.27% |
| Exceedances of Weight | 2 | 0.55% |
| Total Exceedances | 25 | 6.81% |

The year with the most violations of both concentration and weight was 2019. These occurrences were observed after a year of no reported violations. In the following years (2020 and 2021), exceedances decreased back to the low levels observed in 2017. Of the four seasons, samples exceeding the concentration standard seem to be most prevalent during the summer and winter months. Exceedances of the weight standard were only observed during the spring. Though periodic, local impacts may not be captured by these results, water quality throughout the East Fork San Jacinto River watershed is unlikely to be impacted by TSS from WWTFs at the watershed level. A seasonal analysis showed that samples exceeding the concentration standard occurred with the highest frequency in winter and summer months, but the overall percentage of samples exceeding the standards compared to the total number of reports was negligibly small. Despite this, observing TSS in WWTF effluent is still worth considering when moving forward with best management practices for water quality. As mentioned previously, TSS is often correlated with nutrient and bacteria levels, and can be tracked as a measure of WWTF improvement.

### Ammonia Nitrogen

Ammonia nitrogen is a component that indicates negative impacts to water quality due to nutrient loading. Further, it can be toxic to humans and wildlife. Deficiencies in wastewater treatment that lead to improperly treated sewage entering waterways can be indicated by elevated levels of ammonia nitrogen. Similar to TSS, concentration and weight measurements are used to assess compliance of ammonia nitrogen levels with permit limits. In **Table 11** below, the results of samples reported to be in exceedance of the limits as reported between 2017 and 2021 are summarized.

Table 11. DMR ammonia nitrogen exceedance statistics, 2017 to 2021

| Category | Number | Percent of Records |
|---|---|---|
| Facilities in DMR Dataset | 10 | |
| Facilities Reporting Ammonia Nitrogen | 9 | |
| Total Records | 367 | |
| Exceedances of Concentration | 25 | 6.81% |
| Exceedances of Weight | 5 | 1.36% |
| Total Exceedances | 30 | 8.17% |

As seen with TSS, the most exceedances observed in one year occurred in 2019 after relatively low occurrences of exceedances in preceding years. When observed seasonally, exceedances of concentration and weight standards for ammonia nitrogen do seem to occur more frequently in the summer months. However, the total number of exceedances reported for ammonia nitrogen comprise less than 9% of the total reported values. This indicates that WWTFs are generally operating within permit limits and that ammonia inputs from WWTFs are not likely a chronic issue of importance for East Fork San Jacinto River waterways. Periodic, localized impacts may not be as apparent when using a broad scope analysis. Ammonia nitrogen may still have use as an indicator of WWTF efficiency much in the same way as TSS and will therefore continue to be considered for best management practices in the watershed.

### Oxygen Demand

$CBOD_5$ measures the depletion of oxygen over time by biological processes and indicates the efficiency of treatment. It is not a pollutant itself but is informative of the water quality of effluent from WWTFs. In **Table 12** below, the exceedances of concentration and weight limits for $CBOD_5$ in relation to the total number of reported values are summarized.

Table 12. DMR $CBOD_5$ exceedance statistics, 2017 to 2021

| Category | Number | Percent of Records |
|---|---|---|
| Facilities in DMR Dataset | 10 | |
| Facilities Reporting $CBOD_5$ | 9 | |
| Total Records | 367 | |
| Exceedances of Concentration | 6 | 1.64% |
| Exceedances of Weight | 0 | 0.0% |
| Total Exceedances | 6 | 1.64% |

Annual exceedances were only observed in 2019 and 2020. Seasonally, there does seem to be a higher occurrence of exceedance in cooler spring and winter months. However, as with bacteria and DO, it should be noted that determining a trend from exceedance values occurring at such low frequencies might be misrepresentative of the overall dataset. From this analysis, it can be assumed that WWTFs are not likely a chronic source of poor CBOD5 values in the East Fork San Jacinto River watershed. As with previous analyses however, it should be noted that determining periodic and localized impacts may require further investigation.

### Discharge Data Analysis Summary

Exceedances for all constituents compared to their permit limits were revealed in this analysis. However, plants in the East Fork San Jacinto River watershed were largely found to be in compliance with their permit limits for the majority of the period of study. It is unlikely that WWTFs are an appreciable source of contamination in the watershed on a chronic, wide-ranging scale. However, this broad analysis may underrepresent localized impacts of WWTF outfalls.

WWTFs may not be the largest source of bacteria, but effluent from these facilities has an inherently higher pathogenic potential than other sources due to the treatment of human waste. Additionally, unlike other sources of natural and diffuse fecal waste in the watersheds, WWTF effluent has both regulatory controls and voluntary measures by which improperly treated wastewater may be addressed. Given the nature of WWTF effluent as a human pollutant, and our direct ability to influence its character, WWTF bacteria should be considered as a potential focus for some best management practices. While other constituents (e.g., nutrients) are not necessarily any more harmful than other sources in the watershed, the principle of direct control of effluent applies to their consideration as well.

### Sanitary Sewer Overflows

Though SSOs occur episodically, they represent a high-risk vector for bacteria contamination because they can have concentrations of bacteria several orders of magnitude higher than treated effluent. Untreated sewage can contain large volumes of raw fecal matter, making it a significant health risk where SSOs are sizeable and/or chronic issues. The causes of SSOs vary from human error to infiltration of rainwater into sewer pipes. Data used for these analyses is self-reported and may vary in quality. Even in the best of circumstances, the ability to accurately gauge SSO volumes or even occurrences in the field is limited by several factors. Actual SSO volumes and incidences are generally expected to be greater than reported due to these fundamental challenges. Known causes of SSOs were broken into four broad categories with several subcategories each, to reflect the breakdown in TCEQ's SSO database. It should be noted, however, that this categorization depends on the accuracy of the data reported by the utilities. Additionally, while a single cause is typically listed on the SSO report, many SSOs are caused by a combination of factors.

This study considered five years of TCEQ SSO violation data from 2017 to 2021. There were 22 SSO records from seven facilities considered for the watershed area. Of those, two plants had ≥ 5 SSOs, and of those two plants, only one had ≥ 10 SSOs. Number of SSOs generally corresponded to volume of SSOs.

The highest number of SSOs observed in one year occurred in 2019 as shown in **Table 13**. In terms of cause by number, the general category of weather-related issues accounted for 50.0% of the overall total, malfunctions and operational issues accounted for 40.9%, and 9.1% were listed as blockages.

Table 13. Number of annual SSO events

| CAUSE | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|
| **Weather** | **2** | **0** | **6** | **0** | **3** |
| *Rain / Inflow / Infiltration* | 1 | | 4 | | 3 |
| *Hurricane* | 1 | | 2 | | |
| **Malfunctions** | **4** | **0** | **1** | **3** | **1** |
| *WWTF Operation or Equipment Malfunction* | 2 | | | 1 | |
| *Power Failure* | | | | | |
| *Lift Station Failure* | | | 1 | | |
| *Collection System Structural Failure* | 1 | | | 1 | 1 |
| *Human Error* | 1 | | | 1 | |
| **Blockages** | **0** | **0** | **1** | **1** | **0** |
| *Blockage in Collection System-Other Cause* | | | | 1 | |
| *Blockage in Collection System Due to Fats/Grease* | | | | | |
| *Blockage Due to Roots/Rags/Debris* | | | 1 | | |
| **Unknown Cause** | **0** | **0** | **0** | **0** | **0** |
| **TOTAL** | **6** | **0** | **8** | **4** | **4** |

While numbering SSO events informs how frequently these overflows impact the watershed, volume of overflow is an indicator of the magnitude of impact. The results summarized in **Table 14** indicate that as with number of events, the highest annual volume of SSOs occurred in 2019. Of note, though 2017 had only the second highest total overflow volume reported over the five years of study, over 73% of the overflow volume was associated with a hurricane event (Hurricane Harvey). High flows associated with Tropical Storm Imelda in 2019 yielded over 84% of the annual SSO volume.

Table 14. Annual SSO events by volume (in gallons)

| CAUSE | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|
| **Weather** | **45,000** | **0** | **294,100** | | **51,00** |
| *Rain / Inflow / Infiltration* | 5,000 | | 156,100 | | 51,000 |
| *Hurricane* | 40,000 | | 138,000 | | |
| **Malfunctions** | **9,300** | **0** | **54,000** | **10,600** | **1,000** |
| *WWTF Operation or Equipment Malfunction* | 6,700 | | | 5,000 | |
| *Power Failure* | | | | | |
| *Lift Station Failure* | | | 54,000 | | |
| *Collection System Structural Failure* | 2,500 | | | 4,800 | 1,000 |
| *Human Error* | 100 | | | 800 | |
| **Blockages** | **0** | **0** | **150** | **100** | **0** |
| *Blockage in Collection System-Other Cause* | | | | 100 | |
| *Blockage in Collection System Due to Fats/Grease* | | | | | |
| *Blockage Due to Roots/Rags/Debris* | | | 150 | | |
| **Unknown Cause** | **0** | **0** | **0** | **0** | **0** |
| **Total** | **54,300** | **0** | **348,250** | **10,700** | **52,000** |

Of the total volume of overflows reported from 2017 to 2021, weather was responsible for 83.8%. Malfunctions comprised 16.1% of the overall volume, and blockages led to the remaining 0.1%. These overall contributions are important to consider in a general sense for estimating impacts to the watershed area.

### Report Data Analysis Summary

Of the seven plants that reported SSOs between 2017 and 2021, two had ≥ five SSOs, and only one plant had ≥ 10. The number of occurrences followed a similar pattern to that of overflow volume. There was not a strong annual or seasonal trend in number or volume of SSOs aside from the highest frequency and volume events occurring in 2019 in conjunction with Tropical Storm Imelda. In terms of general cause, weather accounted for the highest number of events and overflow volume respective to the other general categories of malfunctions, blockages, and unknown causes.

While this data is useful, it should be noted that it is also self-reported and may vary in quality. Overflow volumes and numbers of events may be greater than the values recorded in the report data. In addition, causes may be overgeneralized due to multiple factors ultimately resulting in SSOs.

In watersheds where bacteria loading is of particular concern, the impacts of SSOs are important to understand due to their concentrations of untreated human waste. These events pose a high risk to human health especially due to their proximity to urban populations. Further, despite their episodic occurrences, SSOs can be extreme loading sources in the sense of volume introduced in a short time frame. Though SSOs do not have the same potential to have chronic impacts on waterways as effluent from high volume WWTFs, for the aforementioned reasons, it is still critical to consider SSO management among the best management practices selected to improve water quality in the East Fork San Jacinto River watershed.

### Summary of Water Quality Analyses

This review of water quality data is foundational for understanding and characterizing water quality concerns in the East Fork San Jacinto River watershed, and for informing subsequent stakeholder decisions. The analyses served to answer questions regarding the sufficiency of the data, the extent and severity of water quality trends, seasonality of water quality issues, and the potential impact of wastewater effluent and SSOs.

Data meeting the criteria for sufficiency were used to determine what constituents of water quality are of greatest concern and the extent to which their impacts have been observed throughout the area waterways. Results from the 2022 Texas Integrated Report for this watershed and the SWQM dataset from 2011 to 2021 identified high levels of the fecal indicator bacteria *E. coli* as the most pervasive impact to water quality.

Permitted wastewater effluent was unlikely to be a widespread or chronic water quality issue but requires further investigation on limited spatial scales and timeframes. However, understanding these discharges is still critical to the development of this project as WWTFs without permit limits for certain nutrients act as source loads—particularly in effluent-dominated streams. Further, as treatment facilities for human waste, improper treatment indicators identified in DMR analyses can have greater implications for risk to human health.

An analysis of SSO reports from the East Fork San Jacinto River watershed indicated that 28.6% of reporting plants experienced five or more SSO events between 2017 and 2021. Patterns in number of events were representative of patterns observed in magnitude of overflow volume. For both number of SSO events and volume of overflow, weather was the most common for the general cause categories. However, it is important to note that while only one cause is usually listed on the report, multiple compounding factors can lead to SSOs. Ultimately, causes listed in SSO reports are prone to a degree of subjectivity as opposed to more quantitative measurements. While the episodic overflow volumes reported during these events are relatively small compared to the scale of effluent produced by WWTFs, SSO inputs are of particular concern due to the untreated nature of the sewage associated with them and the subsequent risk to human health.

As future growth projections indicate that increased development in the watershed is likely, the balance of pollutant sources and current hydrologic processes could be altered significantly in the coming years. These changes could result in further water quality impacts without intervention. Subsequent efforts should be made to identify causes and sources of the primary constituent of concern (indicator bacteria), and to characterize nutrient sources further to identify areas within the project watersheds most vulnerable to pollutant loadings and/or best suited for the implementation of management strategies.

## Source Identification

Using the information generated through the water quality data analyses, the next step in characterizing pollution in the watershed was to evaluate potential causes and sources. The results of this source identification and prioritization process assisted the Partnership in understanding the range of potential sources and guided the subsequent modeling efforts that estimated the loads from fecal waste and nutrient sources. Fecal waste sources were the primary focus of these efforts.

### Fecal Waste Source Identification

Waste from all warm-blooded animals is a potential source of *E. coli* contamination. *E. coli* are not necessarily themselves the source of potential health impacts; however, they signify the presence of fecal waste as well as a host of other pathogens associated with fecal waste. There is a wide array of potential fecal waste sources in the watershed. The potential mix of sources in a watershed can vary greatly in both spatial and seasonal contexts.

#### Source Survey

Characterizing fecal waste pollution in watersheds, and development of analyses to estimate potential loading, requires a consideration of potential sources. In any watershed with a mix of land uses, fecal waste can be produced by a broad mix of sources; this is especially true in a large, diverse watershed like East Fork San Jacinto River. The existence and location of some sources are known from existing data (e.g., WWTF outfalls), while many nonpoint sources need to be evaluated from a mix of literature values, land cover analysis, imagery and road reconnaissance, and a robust process of stakeholder review and feedback. As part of developing the source survey, the Partnership completed the following assessments:

- **Known Source Characterization** — Existing data was used to generate information on discrete (usually permitted) sources. Data sources included[26]:
    - WWTF outfall locations and DMRs (TCEQ outfall locations and DMR records)
    - Permitted on-site sewage facility (OSSF) locations (H-GAC proprietary data provided by local governments)
    - SSOs (TCEQ SSO database)
- **Land Cover Analysis** — Staff reviewed national land cover datasets and H-GAC proprietary land cover datasets to determine the mix of land cover types within the watershed, and within each subwatershed, in a spatial context. The watershed includes a mix of land cover types, so no sources were eliminated based on lack of land cover (*i.e.*, available habitat/use). Statistics and spatial coverage developed during this analysis were used as the basis of populating diffuse sources whose assumptions were tied to specific land cover types in modeling efforts.
- **Stakeholder Feedback** — Stakeholder engagement was a primary focus of the source survey. Local knowledge was a key aspect of understanding source composition in the area. Project staff engaged stakeholder consideration of sources through:
    - Direct discussion of sources at Partnership meetings
    - Direct discussion of sources at source-based Work Group meetings
    - One-on-one meetings with local stakeholders
    - One-on-one meetings with state and regional experts/agencies (*e.g.*, the Texas Parks and Wildlife Department (TPWD), TSSWCB, and others)

In general, stakeholder feedback upheld staff expectations of usual sources, and helped refine extent and scale of expected source contributions (*e.g.*, presence of deer in developed areas, hog activity levels, *etc.*). The ultimate selection of sources to include in the model was based on stakeholder decisions and affirmation of H-GAC's proposed modeling methodology, through the revision process.

### Estimating *E. coli* Loads

Understanding the distribution and relative prominence of various sources of fecal waste is crucial to empowering stakeholders to make informed decisions about potential solutions. To quantify the potential number of fecal indicator bacteria being generated in the watershed, the Partnership used a combination of stakeholder knowledge and

[26] More information on data sources and quality objectives can be found in the project quality assurance project plan (QAPP), available online on the project website at: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_eastforkmodelqapp_qtrak22-265.pdf

computer modeling. The goal was to identify how much *E. coli* was being generated by each source, and how those sources were distributed in the watershed.

### Spatially Explicit Load Enrichment Calculation Tool

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) is a Geographic Information System (GIS)-based analysis approach developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University[27]. The intent of this tool is to estimate the total potential *E. coli* load in a watershed and to show the relative contributions of individual sources of fecal waste identified in the source survey. Additionally, SELECT adds a spatial component by evaluating the total contribution of subwatersheds, and the relative contribution of sources within each subwatershed. SELECT generates information regarding the total potential *E. coli* load generated in a watershed (or subwatershed) based on land use/land cover, known source locations (WWTF outfall locations, OSSFs, *etc.*), literature assumptions about nonpoint sources (pet ownership rates, wildlife population statistics, *etc.*) and feedback from stakeholders. The potential source load[28] estimates are not intended to represent the amount of *E. coli* actually transmitted to the water, as the model does not account for the natural processes that may reduce pollutants on their way to the water, or the relative proximity of sources to the waterway.

Project staff used an adapted SELECT approach to meet the specific data objectives of this project. The implementation of SELECT used for this modeling effort builds on the original tool by adding two modified components.

- **Buffer Approach** — The stock SELECT model assumes all *E. coli* generated within a watershed will have the same impact on instream loads. For example, loads generated 2 miles from a waterway are counted the same as equivalent loads generated within the riparian corridor. Realistically, loads generated adjacent to the waterways are more likely to contribute to instream conditions. However, SELECT does not provide a means by which to model fate and transport factors. In a situation in which a particular source is generally located farther from the waterway, it may be overrepresented compared to a source generally located adjacent to the waterway. For example, if OSSFs in a watershed produced 50 units of waste, but were generally located far from the water, while livestock in a waterway produced the same amount of waste, but generally in the riparian corridor, SELECT would treat these potential loads as equal. For stakeholders making decisions on prioritizing best management practices (BMPs) and sources, this

[27] Additional information about SELECT can be found at: http://ssl.tamu.edu/media/11291/select-aarin.pdf

[28] References to loads in this section, unless specifically stated otherwise, should be taken to refer to (potential) source loads, rather than instream loads. As indicated previously, SELECT does not generate instream loading estimates, just the potential source load prior to factors affecting the fate and transport of pollutants.

is a false equivalency. To strike a balance between project focus on simple but effective modeling and a desire to understand the potential impact of transmission, this implementation of SELECT differentiates between loads generated inside a buffer area surrounding waterways, and loads generated outside this area. The buffer approach assumes 100 percent of the waste generated within 300 feet of the waterway as being transmitted to the watershed without reduction. Outside of that buffer, only 25 percent of the waste is assumed to be transmitted to the waterway[29]. Sources that lack specific spatial locations (unlike permitted outfalls) are assumed to be distributed uniformly in appropriate land uses, inside and outside the buffer. For example, the total number of deer in the buffer is derived from multiplying the assumed density by the numbers of acres of appropriate land use within buffered areas. This approach is designed to provide a very general conception of the effect of distance from the waterway.

- **Future Projections** — The East Fork San Jacinto River watershed is forecasted to experience developmental change. Sources estimated based on data collected as of the year 2022[30] are expected to expand in the future. Therefore, *E. coli* reductions based on current conditions would be inadequate to meet future needs. This implementation of SELECT uses regional demographic projection data to estimate future conditions through 2050 in 5-year intervals[31]. Land use change is the primary driver for estimating changes in source contribution, and spatial distribution of loads[32].

Watershed conditions can change greatly from year to year based on rainfall patterns, agricultural activities, increased urbanization, and other landscape-scale factors. To

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[29] Buffer percentages were based on previously approved WPPs and reviewed on multiple occasions with project stakeholders.

[30] References to "current" modeled conditions throughout this document refer to 2022 estimations, based on the available data at the time of the modeling effort.

[31] 2045 was chosen as a horizon year to coincide with the extent of the regional demographic model projections at the time and also in consideration of likely planning horizon for partner efforts and developmental projects.

[32] All future projections have some level of uncertainty that cannot be wholly controlled for. The H-GAC Regional Growth Forecast (http://www.h-gac.com/regional-growth-forecast/default.aspx) demographic model projections are widely used in the region and in similar WPPs, and thus considered the best available data for making these projections. Some wildlife sources have additional levels of uncertainty because the model assumes that change between land uses eliminates populations tied to the former land use. However, there is not adequate data or analytical approaches within the scope of this project to determine the potential that wildlife populations will change or consolidate by literature values alone. For example, the model assumes a set density of feral hogs per unit of area, populated in appropriate land cover types. Feral hog populations are assumed to stay static because there is insufficient data to make assumptions about rate of population growth. Additionally, if an area containing feral hogs converts to developed land cover, the hogs attributed to that area are eliminated from the calculations. In real conditions, this may instead lead hogs to consolidate in greater densities in remaining habitat up to some carrying capacity. This project acknowledges that uncertainty, and the stakeholders discussed potential methods to address it. However, no sufficient data sources or modeling methods within the scope of this project have been identified to account for wildlife population dynamics. Continual assessment of wildlife populations as a source is recommended in the adaptive management recommendations of the WPP to help overcome this uncertainty.

balance this inherent degree of variation and uncertainty, stakeholder feedback on sources, model assumptions, and results were used heavily through the generation of the analysis and its eventual use as a prioritization tool for selecting BMPs. The goal of the SELECT modeling in this WPP effort, other than the general characterization of source loading, is to aid in prioritizing which sources to address by showing their relative contributions and locations. The loads generated by SELECT are combined with reduction percentages derived from the models explained in Section 4 to generate source reduction loads. There is an inherent level of uncertainty in any modeling of a dynamic system, but the approach used in this WPP is balanced against the end use of the information to support stakeholder decisions.

The analysis design for this process includes four primary steps:

1) Development of a source survey using known locations/sources, suspected sources derived from projects in similar areas, and stakeholder feedback,
2) Stakeholder review of proposed sources and preliminary population/loading assumptions,
3) Implementation of the model and internal quality review, and
4) Stakeholder review of results and model revision as necessary (**Figure 12**).

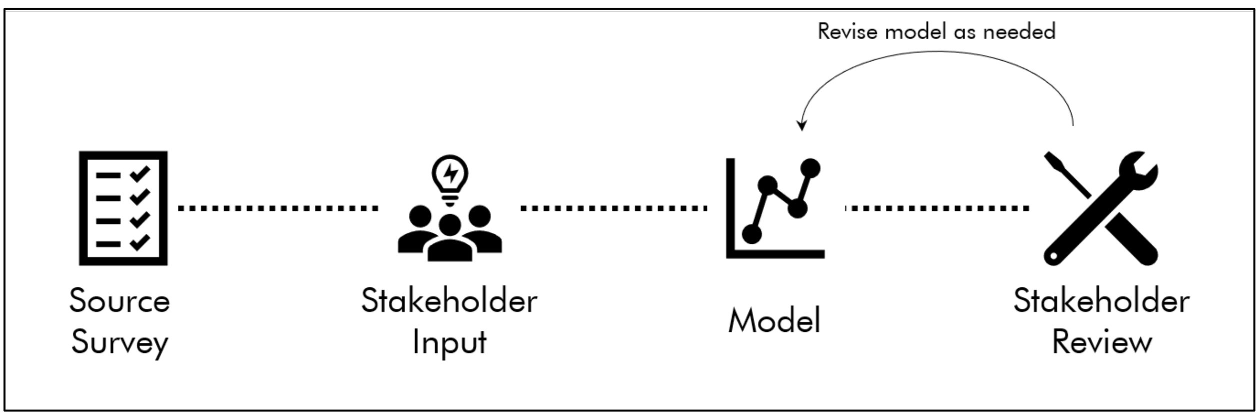


**Figure 12**. SELECT modeling process

The following subsections detail the sources modeled, including the data used and the feedback received from stakeholders. The maps indicate the relative distribution of source loads and populations, while the charts indicate the relative contribution of different sources. The loadings are given in numbers of billions of *E. coli* per day. The map for each specific source is not comparable to other sources; they show the relative distribution for a given source by color gradation, rather than color being tied to absolute load. The maps also reflect the use of the buffer approach. A 300-foot buffer around each waterway (appearing as a series of lines on the map) displays loading in these areas separate from the greater land area using the same color scale. Note that major waterways are represented in blue for spatial reference. Colors associated with the loading value within the riparian buffer for each subwatershed are consistent but are partially obscured by the main channel vectors.

In viewing the maps, it is important to consider that they display both relative loading by area within a subwatershed (riparian areas versus areas outside the riparian) and between subwatersheds. Lastly the map coloration is based on relative load density (load per acre). Larger subwatersheds will have larger loads, all things being equal. Load density maps help equalize discrepancies in subwatershed size and make fair comparisons.

#### Wastewater Treatment Facilities

Wastewater utilities serve a number of communities throughout the watershed and occur in various sizes and capacities. For areas outside city boundaries, centralized waste treatment is most commonly managed by municipal utility districts and other districts. Discharge monitoring report data was available for 10 permitted WWTFs within the watershed and was incorporated into the SELECT model. Size of WWTFs vary greatly throughout the watershed and ranged between capacities of less than 0.1 MGD to 10 MGD.

WWTFs in the East Fork San Jacinto River watershed are not expected to be major contributors to fecal indicator bacteria loading. However, as the risks associated with human waste processed by WWTFs can be considerable in the event of improper treatment or other localized incidents, it is important to consider estimates of potential WWTF loadings in the overall SELECT model. These estimates are derived by multiplying the total discharge capacity of each facility by the state water quality standard for fecal bacteria. For future projections, models continued to estimate fecal bacteria loads at the state standard but adapted flow rates to reflect the projected increase in the number of households within service area boundaries. As many facilities discharge well below their maximum permitted rates, this results in a potential overestimation of fecal bacteria loading from this source. As noted previously, this method is still deemed appropriate for this watershed in order to account for exceedances or variations throughout daily discharges that could have greater impacts to public health.

Current WWTF loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into East Fork San Jacinto River are represented in **Figure 14**. As loads were estimated solely from outfall data within the riparian buffer, all spatial results are indicated within the buffer zone surrounding the watershed stream network (no data is available for the land area beyond the buffer). Color intensity indicates loading severity relative to the other streams and may not be directly comparable between this modeled parameter and the remaining sources examined with SELECT analyses. Actual loading estimates by subwatershed are represented in **Table 15**. In **Figure 13**, forecasted total watershed loads from WWTFs are plotted in five-year increments through the year 2050.

**Table 15.** Wastewater facility outfalls and loadings in billion cfu/day by subwatershed

| Subwatershed* | # of Outfalls | *E. coli* Load Estimate in Billion cfu/day | Subwatershed Percent of Total Load |
|---|---|---|---|
| Lower East Fork SJR (SW1) | 5 | 1.18 | 31% |
| Middle East Fork SJR (SW2) | 2 | 1.56 | 41% |
| Upper East Fork SJR (SW3) | 1 | 0.05 | 1% |
| Winters Bayou (SW4) | 2 | 0.98 | 26% |
| Nebletts Creek (SW5) | 0 | -- | -- |
| Boswell Creek (SW6) | 0 | -- | -- |
| **Total** | **10** | **3.77** | **100%** |

*See **Figure 3** for subwatershed names and location

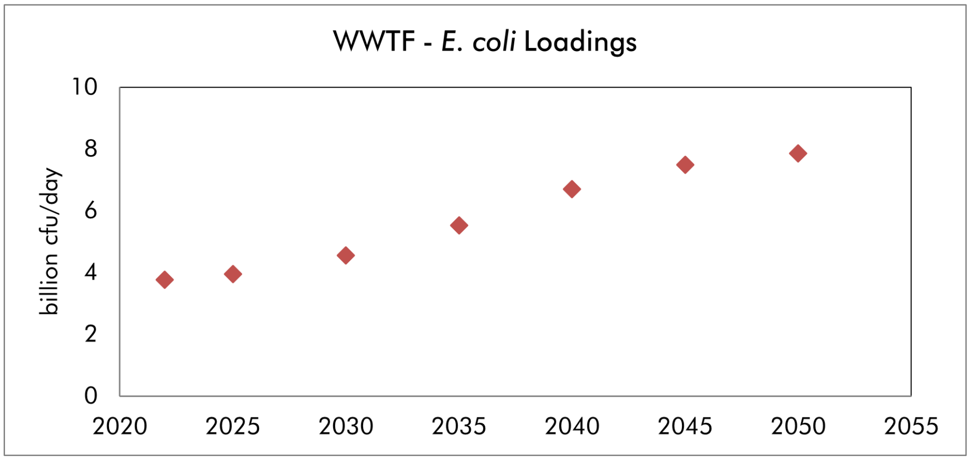


**Figure 13.** Future *E. coli* loadings from WWTFs

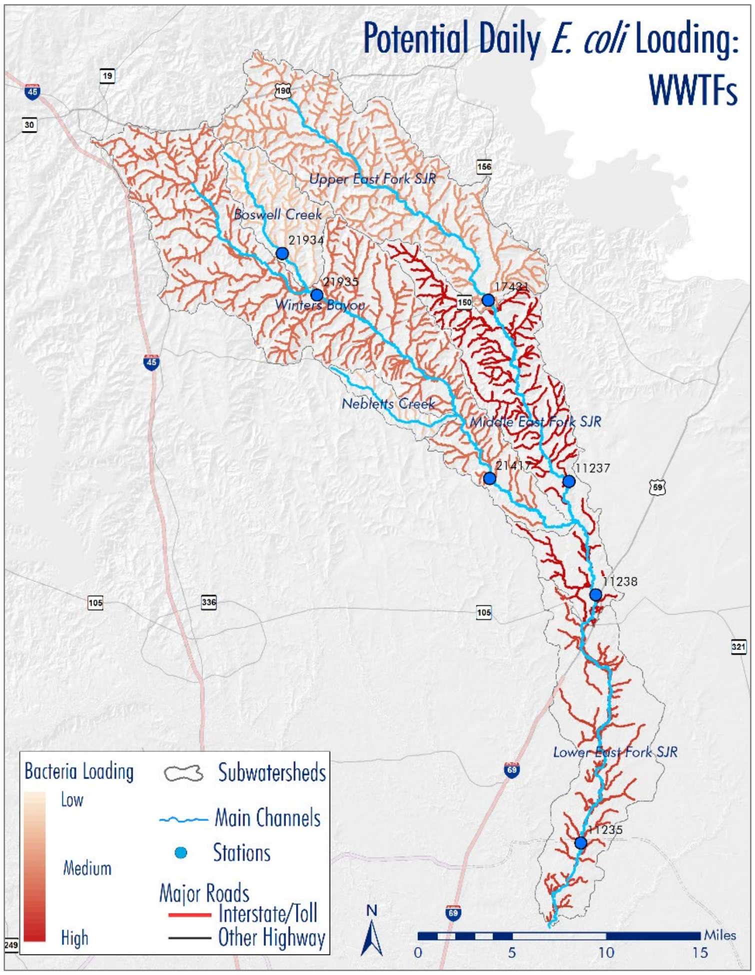


Figure 14. *E. coli* loadings from WWTFs by subwatershed

## On-site Sewage Facilities

While centralized wastewater treatment is more common in developed areas, OSSFs are more likely to be used in parts of the watershed outside service area boundaries such as suburban and rural communities. OSSFs such as conventional and aerobic systems are an efficient and effective way to manage wastewater, however, aging or improperly maintained units run the risk of failing. Significant sources of fecal bacteria can be transmitted to waterways in the event of an OSSF failure.

Estimates of OSSF distribution throughout the East Fork San Jacinto River watershed were made using the spatial data of permitted OSSFs that were collected under a 604(b) agreement between H-GAC and TCEQ and quality assured under the auspices of that contract. Where portions of the watershed overlapped with areas outside the H-GAC region such as San Jacinto County, Texas State Data Center population projections were used. This dataset is not comprehensive as some data may be subject to insufficiencies such as a lack of geocoding. This uncertainty is accounted for in the SELECT model through an estimation of any unrecorded or otherwise unpermitted OSSFs in the watershed area based on land use. Unpermitted OSSFs throughout the watershed were estimated by assessing the number of occupied parcels outside service area boundaries that were not indicated in the permitted OSSF database. Loading rates observed from improperly maintained and failed systems were used to estimate total load contribution from OSSFs. Literature values for OSSF failure rates in the watershed area range between 12 and 19%[33]. For the purposes of this report, a conservative estimate of 10% failure rate was applied to the combined total number of permitted OSSFs and unpermitted OSSFs indicated by the current dataset and for each of the five-year interval projections through 2050. This method has been used for watershed projects in nearby areas and was supported by local stakeholders. However, if more updated values for OSSF failure rates are determined throughout the project period, future evaluations of the WPP that take place as part of the adaptive management process will consider them.

Current OSSF loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into East Fork San Jacinto River are represented in **Figure 16**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 16**. In **Figure 15**, forecasted total watershed loads from OSSFs are plotted in five-year increments through the year 2050.

[33] See: https://www.tceq.texas.gov/assets/public/compliance/compliance_support/regulatory/ossf/StudyToDetermine.pdf

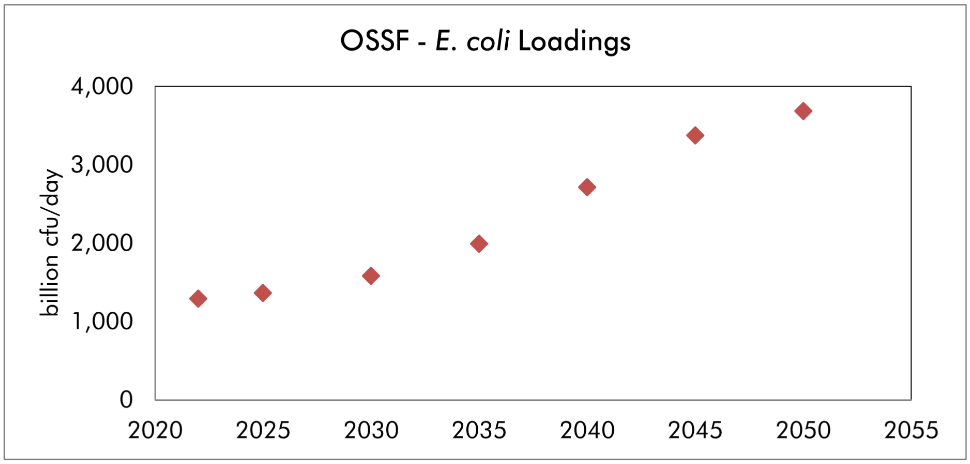


**Figure 15.** Future *E. coli* loadings from OSSFs

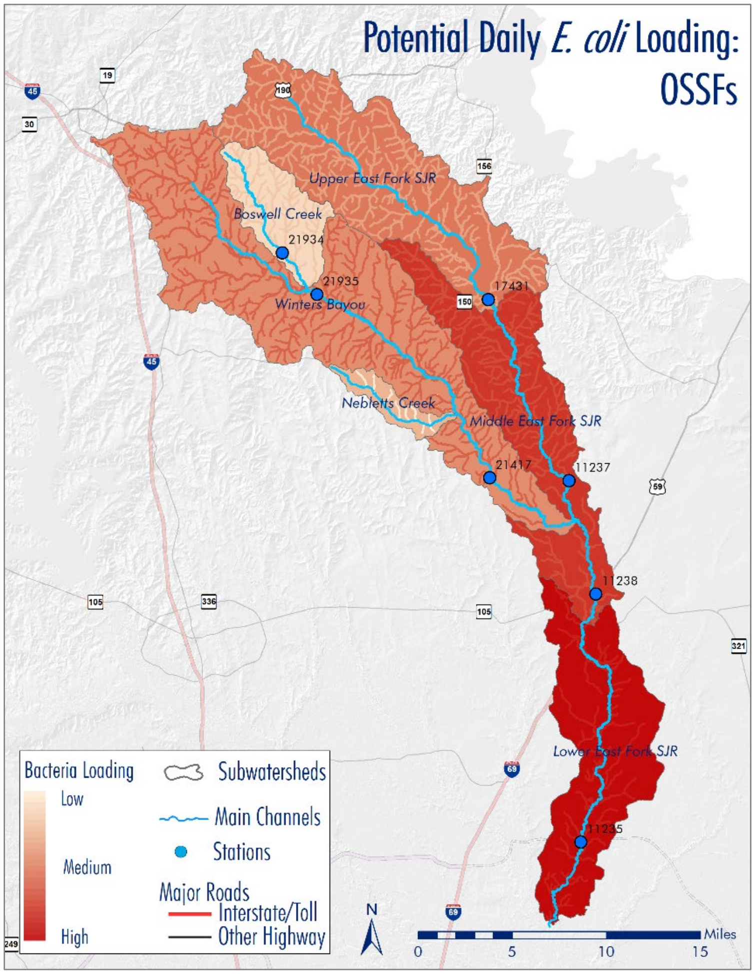


**Figure 16.** *E. coli* loadings from OSSFs by subwatershed

Table 16. OSSFs and loadings in billion cfu/day by subwatershed

| Subwatershed | OSSFs Outside Buffer | OSSFs Within Buffer | *E. coli* Load Outside Buffer | *E. coli* Load Within Buffer | Subwatershed Percent of Total Load |
|---|---|---|---|---|---|
| Lower East Fork SJR (SW1) | 6,560 | 667 | 608.44 | 247.46 | 63% |
| Middle East Fork SJR (SW2) | 1,186 | 268 | 110.00 | 99.43 | 16% |
| Upper East Fork SJR (SW3) | 758 | 140 | 70.30 | 51.94 | 9% |
| Winters Bayou (SW4) | 604 | 244 | 56.02 | 90.52 | 11% |
| Nebletts Creek (SW5) | 149 | 0 | 13.82 | 0.00 | 1% |
| Boswell Creek (SW6) | 6 | 2 | 0.56 | 0.74 | 0% |
| **TOTAL** | **9,263** | **1,321** | **859.14** | **490.09** | **100%** |

### Pet Waste

Domestic and feral dog populations are significant contributors to fecal bacteria contamination in densely developed areas and are a common source of loading in the greater Houston region. Waste from other domestic pets (e.g., cats) is typically managed through collection in waste receptacles, whereas dog waste is more likely to be deposited directly into the environment.

For SELECT analysis, fecal bacteria loading from dog populations will be estimated by assessing pet ownership. Statistical data for Texas established by the American Veterinary Medical Association[34] of 0.6 dogs per household were used in SELECT models. This value was applied to current household data and future projections through 2050. Stakeholder insights on recent efforts to control pet waste including development of pet waste station infrastructure, and community use of waste bags, etc. already underway in the watershed. To account for this, the estimated load based on 0.6 dogs per household was further reduced by 20%. This method has been used in other WPP projects.

Current dog loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into East Fork San Jacinto

[34] For more information, see: https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx

River are represented in **Figure 18**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 17**. In **Figure 17**, forecasted total watershed loads from dogs are plotted in five-year increments through the year 2050.

**Table 17**. Dogs and loadings in billion cfu/day by subwatershed

| Subwatershed | Dogs Outside Buffer | Dogs Within Buffer | *E. coli* Load Outside Buffer | *E. coli* Load Within Buffer | Subwatershed Percent of Total Load |
|---|---|---|---|---|---|
| Lower East Fork SJR (SW1) | 4,840 | 412 | 2,419.80 | 824.40 | 62% |
| Middle East Fork SJR (SW2) | 1,299 | 206 | 649.50 | 412.80 | 20% |
| Upper East Fork SJR (SW3) | 455 | 84 | 227.40 | 168.00 | 8% |
| Winters Bayou (SW4) | 362 | 146 | 181.20 | 292.80 | 9% |
| Nebletts Creek (SW5) | 89 | 11 | 44.70 | 22.80 | 1% |
| Boswell Creek (SW6) | 4 | 1 | 1.80 | 2.40 | 0% |
| **Total** | **7,049** | **860** | **3,524.40** | **1,723.20** | **100%** |

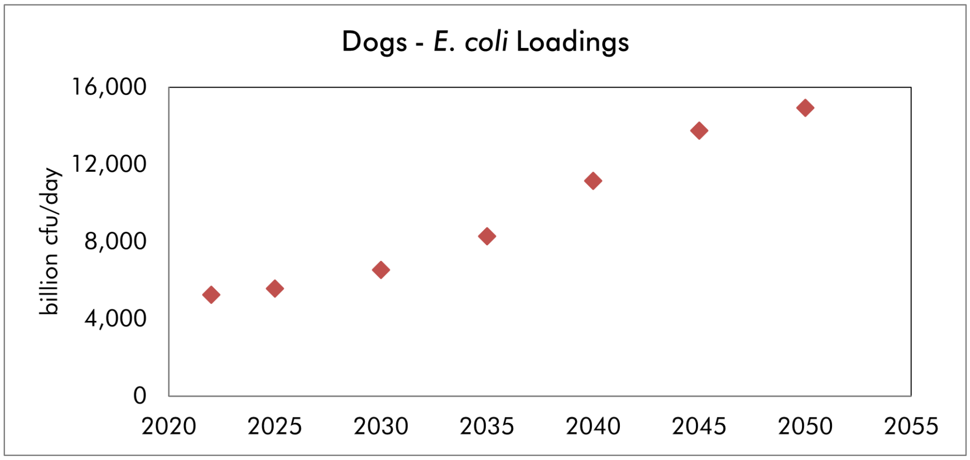


**Figure 17.** Future *E. coli* loadings from dogs

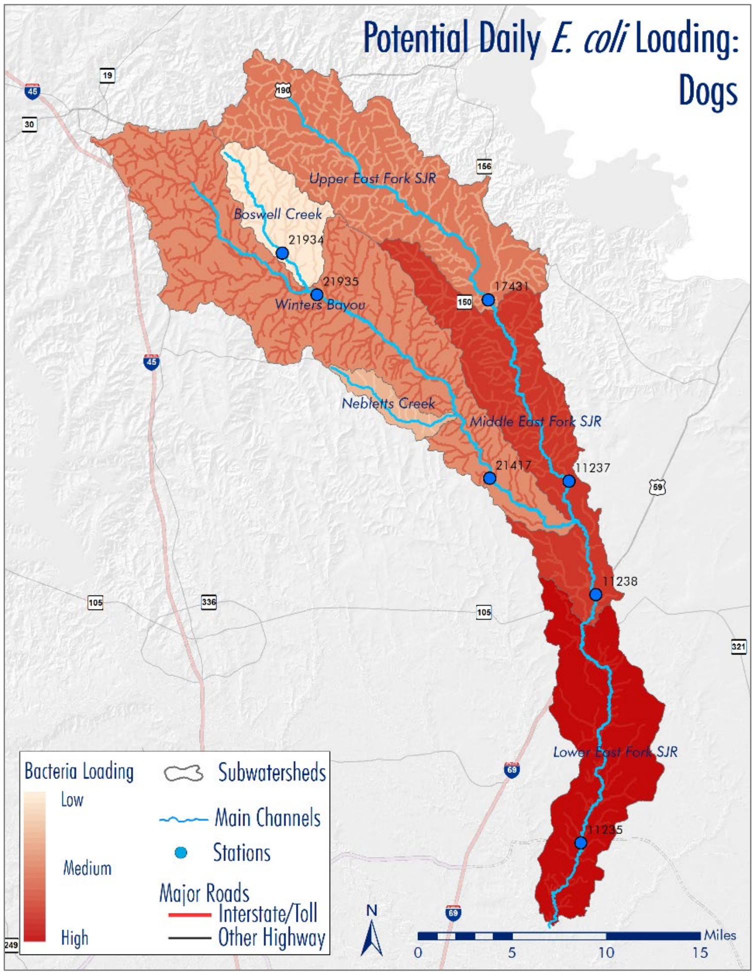


**Figure 18.** *E. coli* loadings from dogs by subwatershed

### Cattle

Agricultural land, grassland, and pastures are most common in the western reaches of the watershed with smaller concentrated areas of these land cover types distributed throughout. National livestock populations including cattle were most recently assessed in a 2017 census by the United States Department of Agriculture. Census data are available by county and are not specific to the watershed area. To estimate cattle in the East Fork San Jacinto River watershed, a ratio of each county's portion of the watershed's acreage in appropriate land cover types to that of the respective county as a whole was applied to agricultural census data from each of the four counties. This approach ensures that the density of cattle in a county's applicable land cover acreage (grassland and pasture/hay) was the same as the density in the watershed's applicable land use acreage. After stakeholder review, this initial estimate was modified further to better reflect observed conditions. Stakeholders indicated that initial estimates distributing cattle populations solely in grassland and pasture/hay land cover areas were inaccurate due to an overestimation of the usage of those areas by cattle. To account for fallow lands or smaller parcels of pasture and grassland not grazed by herds, cattle population estimates were adjusted to 90% of the initial estimate in these land cover areas. Further, stakeholders noted that cattle occasionally use forest and shrubland especially when adjacent to waterways. This observation was reflected in the model by distributing 10% of the cattle population estimate into forested areas within the riparian buffer. Lastly, more updated estimates of daily cattle loading values were incorporated into the analysis[35]. Due to an adjustment from 5.4 billion cfu/day in the initial analysis to 11 billion cfu/day in the revision, livestock values shown here are much greater than those reported in the initial bacteria modeling estimate[36].

Current cattle loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into East Fork San Jacinto River are represented in **Figure 20**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 18**. In **Figure 19**, forecasted total

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[35] See: Coffey et al., 2010 (https://www.sciencedirect.com/science/article/abs/pii/S0378377409002479), Coffey et al., 2013 (https://www.tandfonline.com/doi/abs/10.1080/10807039.2012.701983), and Iqbal and Hofstra, 2018 (https://www.tandfonline.com/doi/full/10.1080/10807039.2018.1487276)
[36] See: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_4.3_bacteria_modeling_report_final.pdf

watershed loads from cattle are plotted in five-year increments through the year 2050.

**Table 18.** Cattle and loadings in billion cfu/day by subwatershed

| Subwatershed | Cattle Outside Buffer | Cattle Within Buffer | *E. coli* Load Outside Buffer | *E. coli* Load Within Buffer | Subwatershed Percent of Total Load |
|---|---|---|---|---|---|
| Lower East Fork SJR (SW1) | 723 | 184 | 1,987.70 | 2,026.89 | 8% |
| Middle East Fork SJR (SW2) | 1,081 | 424 | 2,973.47 | 4,660.75 | 14% |
| Upper East Fork SJR (SW3) | 1,314 | 764 | 3,612.87 | 8,399.02 | 22% |
| Winters Bayou (SW4) | 3,661 | 1,604 | 10,067.42 | 17,648.17 | 52% |
| Nebletts Creek (SW5) | 107 | 28 | 293.84 | 312.22 | 1% |
| Boswell Creek (SW6) | 147 | 129 | 404.63 | 1,419.98 | 3% |
| **Total** | **7,033** | **3,133** | **19,339.93** | **34,467.03** | **100%** |

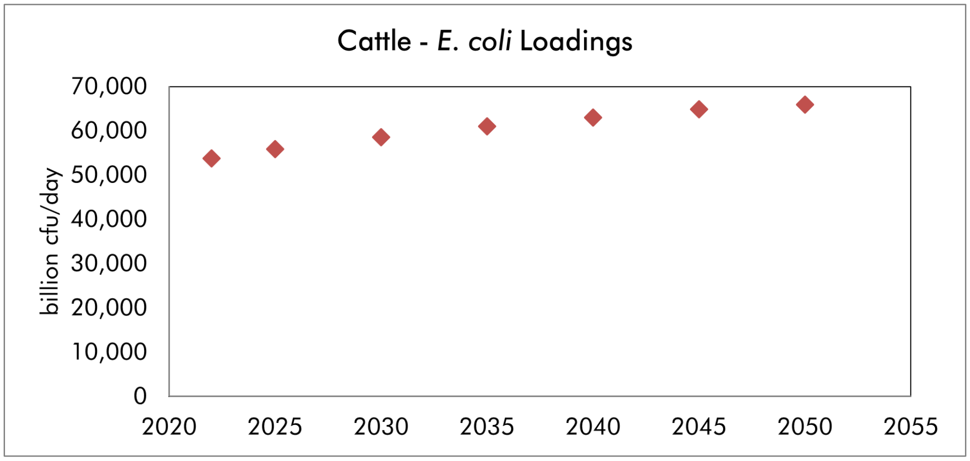


**Figure 19.** Future *E. coli* loadings from cattle

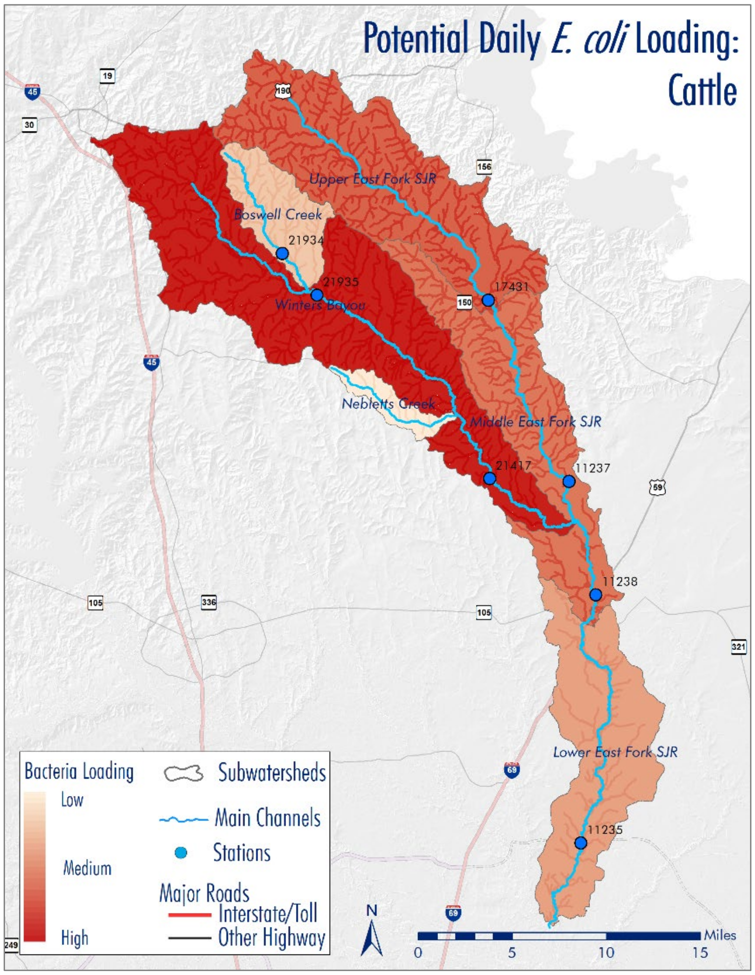


Figure 20. *E. coli* loadings from cattle by subwatershed

## Horses

Similar to cattle, horse population estimates were calculated based on agricultural census data modified by the ratio of watershed area of relevant land use types to total county area. Based on stakeholder feedback, horse populations were similarly distributed 90% to pasture and grassland, and 10% to forested area within the riparian buffer. This method assesses only the horses designated for livestock use in the watershed. Horses owned for recreational purposes may not be well represented by these estimates.

Current horse loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into East Fork San Jacinto River are represented in **Figure 22**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 19**. In **Figure 21**, forecasted total watershed loads from horses are plotted in five-year increments through the year 2050.

**Table 19.** Horses and loadings in billion cfu/day by subwatershed

| Subwatershed | Horses Outside Buffer | Horses Within Buffer | *E. coli* Load Outside Buffer | *E. coli* Load Within Buffer | Subwatershed Percent of Total Load |
|---|---|---|---|---|---|
| Lower East Fork SJR (SW1) | 68 | 17 | 3.56 | 20.41 | 17% |
| Middle East Fork SJR (SW2) | 101 | 40 | 5.32 | 8.34 | 9% |
| Upper East Fork SJR (SW3) | 123 | 72 | 38.14 | 15.03 | 37% |
| Winters Bayou (SW4) | 343 | 150 | 18.02 | 31.59 | 34% |
| Nebletts Creek (SW5) | 10 | 3 | 0.53 | 0.56 | 1% |
| Boswell Creek (SW6) | 14 | 12 | 0.72 | 2.54 | 2% |
| **Total** | **659** | **294** | **66.29** | **78.47** | **100%** |

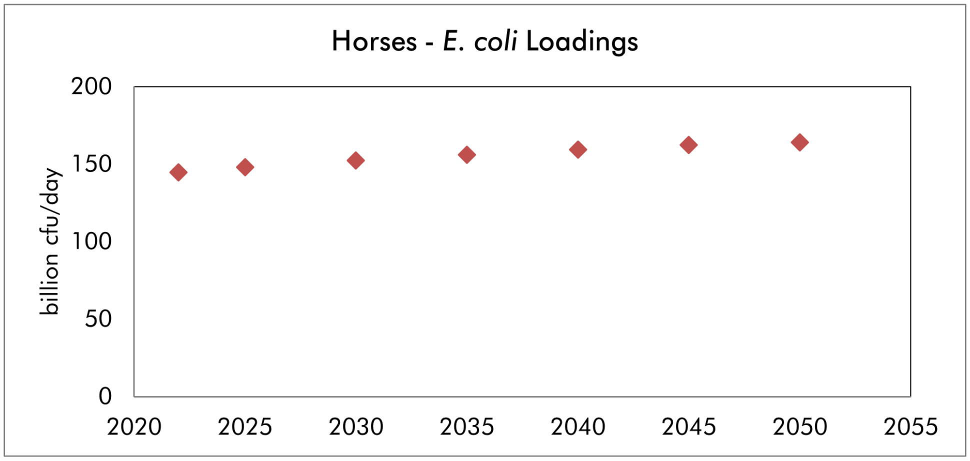


**Figure 21.** Future *E. coli* loadings from horses

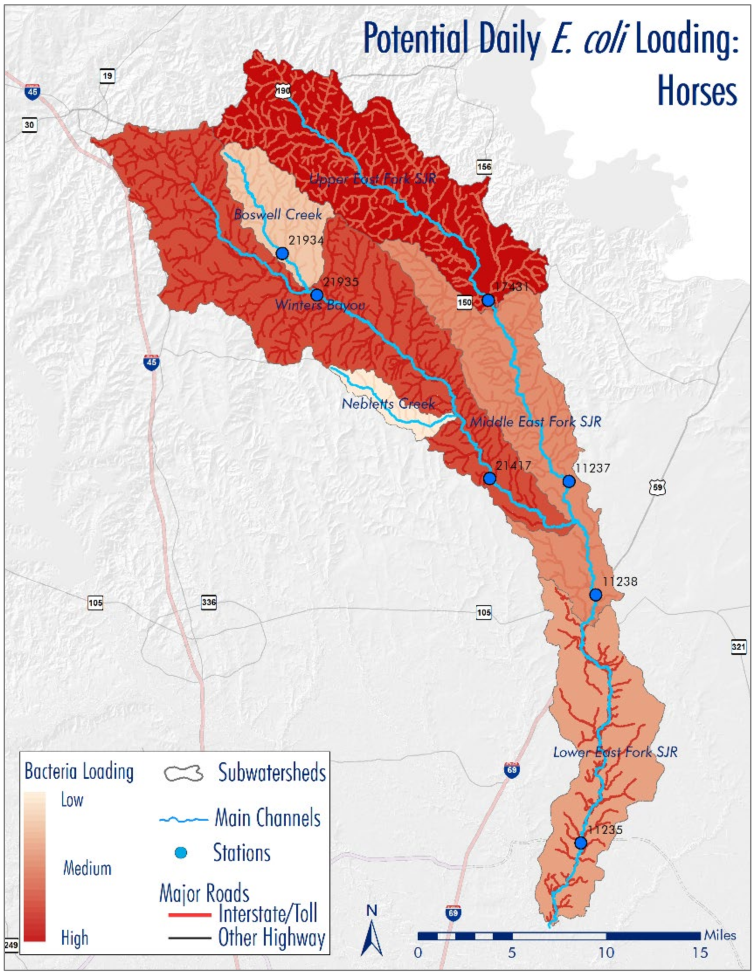


Figure 22. *E. coli* loadings from horses by subwatershed

## Sheep and Goats

Sheep and goat populations represent a smaller portion of the livestock in the watershed, but still retain a presence in rural areas. Both animal populations are grouped into a single statistic in the agricultural census. To estimate the size of these populations, the same method used for cattle and horses was applied to agricultural census data for sheep and goats. Based on stakeholder feedback, sheep and goat populations were similarly distributed 90% to pasture and grassland, and 10% to forested area within the riparian buffer.

Current sheep and goat loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into East Fork San Jacinto River are represented in **Figure 24**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 20**. In **Figure 23**, forecasted total watershed loads from sheep and goats are plotted in five-year increments through the year 2050.

**Table 20.** Sheep and goat loadings in billion cfu/day by subwatershed

| Subwatershed | Sheep & Goats Outside Buffer | Sheep & Goats Within Buffer | *E. coli* Load Outside Buffer | *E. coli* Load Within Buffer | Subwatershed Percent of Total Load |
|---|---|---|---|---|---|
| Lower East Fork SJR (SW1) | 83 | 21 | 186.18 | 189.85 | 8% |
| Middle East Fork SJR (SW2) | 124 | 49 | 278.52 | 436.56 | 14% |
| Upper East Fork SJR (SW3) | 150 | 87 | 338.41 | 786.71 | 22% |
| Winters Bayou (SW4) | 419 | 184 | 942.99 | 1,653.05 | 52% |
| Nebletts Creek (SW5) | 12 | 3 | 27.52 | 29.24 | 1% |
| Boswell Creek (SW6) | 17 | 15 | 37.90 | 133.01 | 3% |
| **Total** | **805** | **359** | **1,811.52** | **3,228.42** | **100%** |

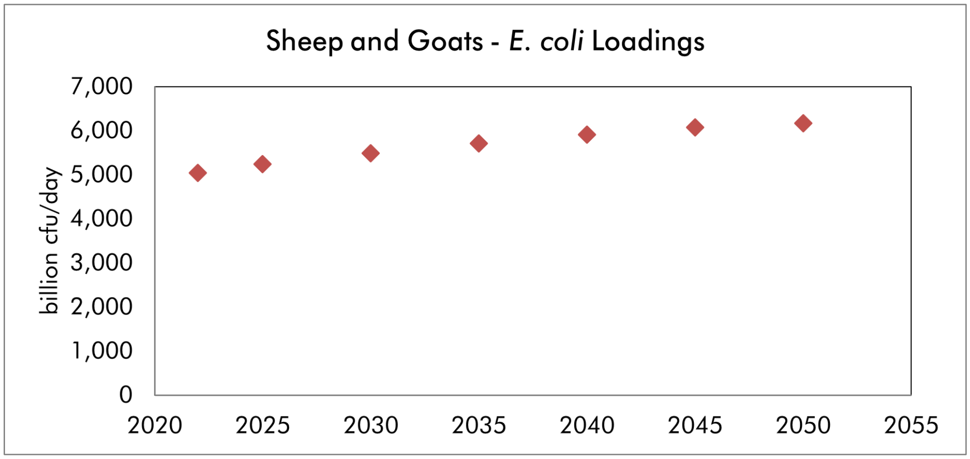


**Figure 23.** Future *E. coli* loadings from sheep and goats

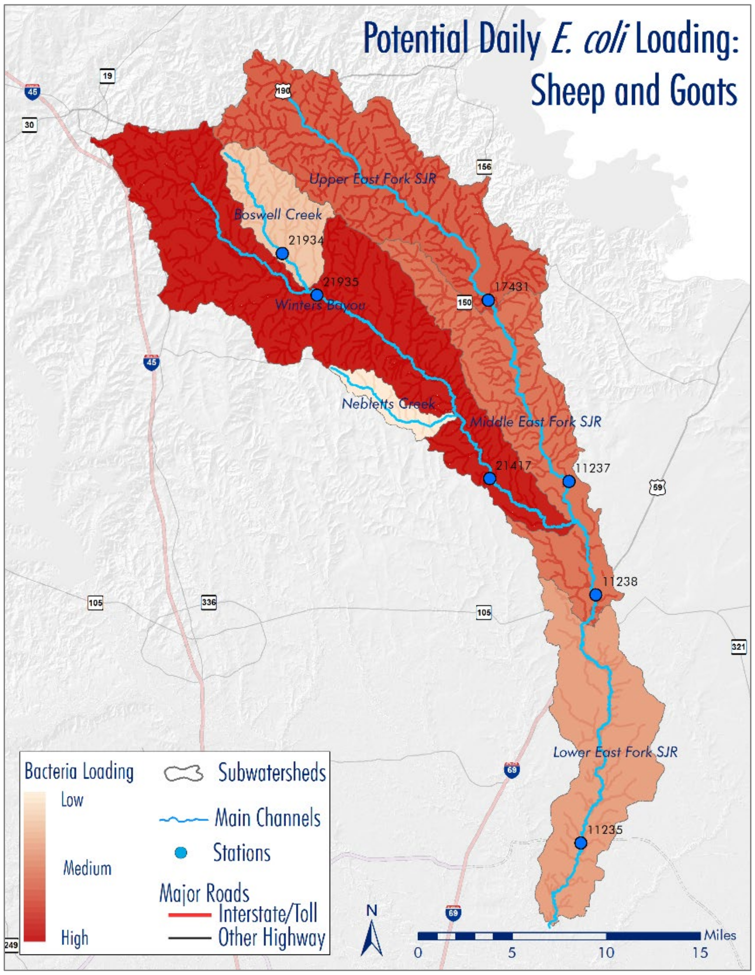


Figure 24. *E. coli* loadings from sheep and goats by subwatershed

## Deer

Forests and open areas in the less developed areas of the watershed provide ample habitat area for white-tailed deer. However, deer are among the few species that are adaptable to the encroachment of developed areas. Loss of natural areas may lead deer to explore larger lots of suburban and light urban development as alternative habitat. Because of this, forested areas and open and low intensity developed areas were considered as possible deer habitat for the purposes of load estimation. To estimate deer populations and their associated fecal bacteria loading potential, Resource Management Unit population density data accessed from the Texas Parks and Wildlife Department assuming 1 deer for every 40.2 acres of forest, shrubland and open developed areas were used. In low intensity developed areas, deer density was assumed to be 1 deer for every 80.4 acres. After consulting with stakeholders, this lower density of 1 deer per 80.4 acres was applied in additional land cover areas including pasture and grassland, wetlands, and barren land. This change was made as stakeholders agreed that deer populations are most concentrated in forested areas but noted seeing deer in areas also used by feral hog populations. Even with this updated approach, population dynamics are not well represented with respect to movements between land cover types and possible increases in density of natural areas after the built environment extends into previously undeveloped spaces.

Current deer loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into East Fork San Jacinto River are represented in **Figure 26**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 21**. In **Figure 25**, forecasted total watershed loads from deer are plotted in five-year increments through the year 2050.

**Table 21.** Deer and loadings in billion cfu/day by subwatershed

| Subwatershed | Deer Outside Buffer | Deer Within Buffer | *E. coli* Load Outside Buffer | *E. coli* Load Within Buffer | Subwatershed Percent of Total Load |
|---|---|---|---|---|---|
| Lower East Fork SJR (SW1) | 622 | 117 | 27.19 | 20.41 | 13% |
| Middle East Fork SJR (SW2) | 642 | 217 | 28.07 | 37.96 | 17% |
| Upper East Fork SJR (SW3) | 872 | 351 | 38.14 | 61.44 | 26% |
| Winters Bayou (SW4) | 1,221 | 450 | 53.40 | 78.74 | 35% |
| Nebletts Creek (SW5) | 89 | 22 | 3.91 | 3.93 | 2% |
| Boswell Creek (SW6) | 241 | 98 | 10.56 | 17.06 | 7% |
| **Total** | **3,687** | **1,255** | **161.27** | **219.54** | **100%** |

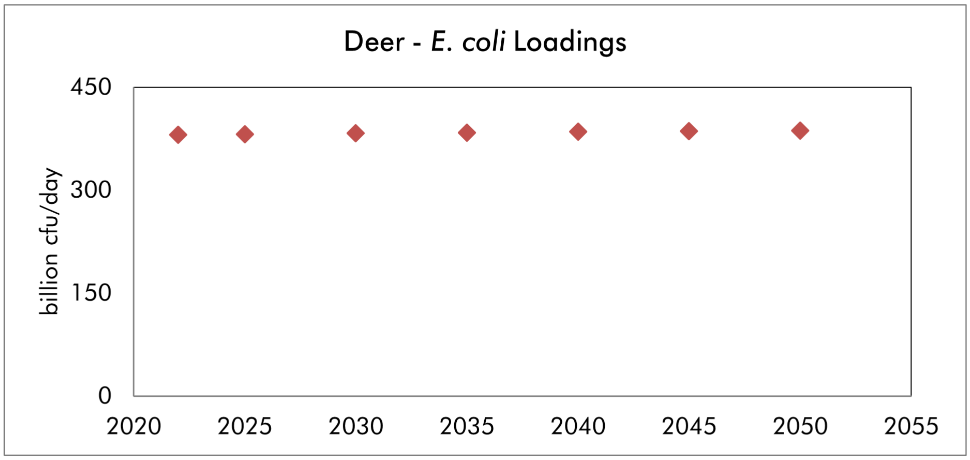


**Figure 25.** Future *E. coli* loadings from deer

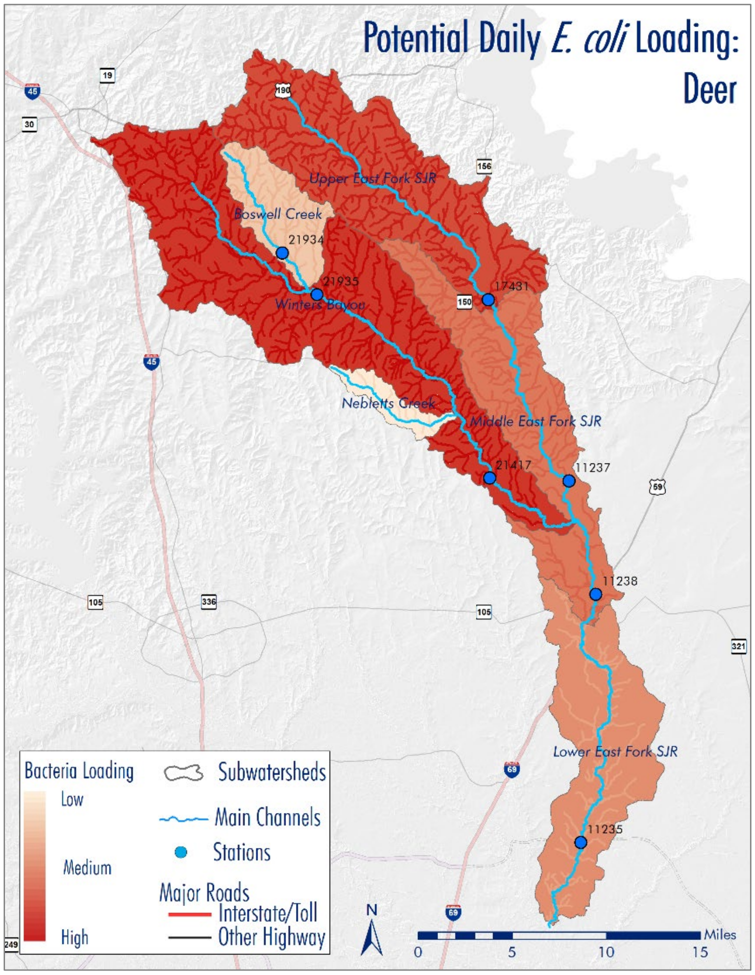


**Figure 26.** *E. coli* loadings from deer by subwatershed

### Feral Hogs

In the Houston-Galveston region feral hogs (*Sus scrofa*) are an invasive species that negatively impact agriculture, wildlife species and their habitats, and human landscapes. Efforts to control feral hogs have been carried out by communities within the East Fork San Jacinto River watershed that have already recognized the environmental pressures associated with their populations. Feral hogs are of particular concern as carriers of diseases that can be dangerous to domestic livestock, pets, and humans. These animals are known to use land around waterways as shelter and transportation corridors between food resources and can generate large volumes of waste where they concentrate.

Though they occur in the highest densities along riparian corridors and other natural areas, feral hogs are pervasive and can be found in all land cover types aside from heavily developed areas and open water. Population density estimates used in the SELECT model for feral hog source loads referenced land cover types in the watershed area based on AgriLife literature values[37]. Though initial estimates accounted for hogs in all land cover areas excluding development and open water, stakeholder feedback about observed hog behaviors and migration in the watershed led to two important changes. First, hog densities were assumed to follow a gradient from heavy densities in more natural land cover type to lighter densities with increasing proximity to development. In **Table 22**, the specific allocation of hog population density based on stakeholder recommendations is described. Second, though no feral hog populations were assumed outside the riparian buffer in medium and high intensity developed areas, half of the lowest density estimate was applied within the riparian buffer in those land types.

[37] For more information, see: http://agrilife.org/feralhogs/files/2010/04/FeralHogPopulationGrwothDensityandHervestinTexasedited.pdf

Table 22. Feral hog population density by land cover type

| Land Cover Type | Outside Buffer | Inside Buffer |
|---|---|---|
| Wetlands | 16.4 hogs/ square mile | 16.4 hogs/ square mile |
| Forest and Shrubland | 16.4 hogs/ square mile | 16.4 hogs/ square mile |
| Grassland | 16.4 hogs/ square mile | 16.4 hogs/ square mile |
| Pasture | 12.7 hogs/ square mile | 12.7 hogs/ square mile |
| Cultivated Cropland | 12.7 hogs/ square mile | 12.7 hogs/ square mile |
| Barren Land | 12.7 hogs/ square mile | 12.7 hogs/ square mile |
| Developed Open Space | 8.9 hogs/ square mile | 8.9 hogs/ square mile |
| Low Intensity Developed<br>Medium Intensity Developed<br>High Intensity Developed | 8.9 hogs/ square mile<br>None<br>None | 8.9 hogs/ square mile<br>4.45 hogs/ square mile<br>4.45 hogs/ square mile |

Current feral hog loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into East Fork San Jacinto River are represented in **Figure 28**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 23**. In **Figure 27**, forecasted total watershed loads from feral hogs are plotted in five-year increments through the year 2050.

**Table 23.** Feral hogs and loadings in billion cfu/day by subwatershed

| Subwatershed | Feral Hogs Outside Buffer | Feral Hogs Within Buffer | *E. coli* Load Outside Buffer | *E. coli* Load Within Buffer | Subwatershed Percent of Total Load |
|---|---|---|---|---|---|
| Lower East Fork SJR (SW1) | 731 | 156 | 1,004.83 | 857.94 | 13% |
| Middle East Fork SJR (SW2) | 755 | 275 | 1,037.70 | 1,512.62 | 17% |
| Upper East Fork SJR (SW3) | 988 | 431 | 1,358.03 | 2,371.82 | 25% |
| Winters Bayou (SW4) | 1,453 | 581 | 1,997.87 | 3,195.20 | 36% |
| Nebletts Creek (SW5) | 101 | 28 | 138.43 | 151.34 | 2% |
| Boswell Creek (SW6) | 261 | 114 | 359.15 | 627.33 | 7% |
| **Total** | **4,289** | **1,585** | **5,896.01** | **8,716.25** | **100%** |

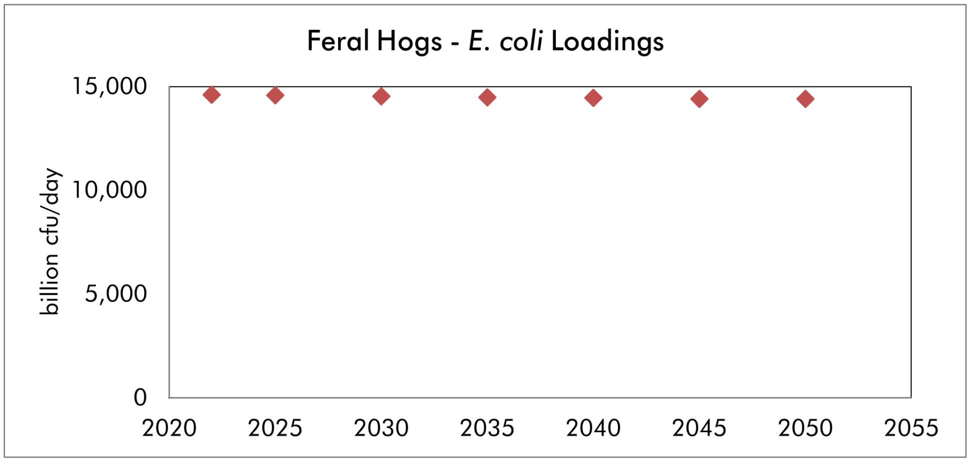


**Figure 27.** Future *E. coli* loadings from feral hogs

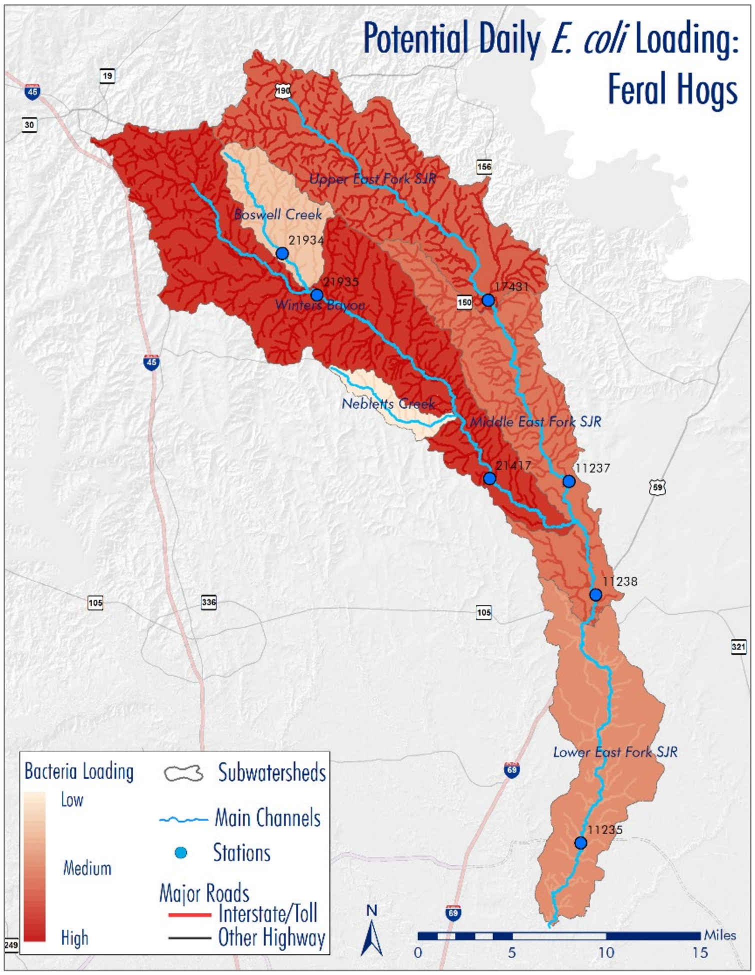


Figure 28. *E. coli* loadings from feral hogs by subwatershed

## Other Sources of Fecal Waste

The primary other potential sources, and the reasons for not including them in the estimates are elaborated upon here. In general, sources which are not specifically included in the SELECT estimates are still potential targets of mitigation as part of the WPP, especially on a localized scale, depending on the source being discussed. While some of the wildlife populations discussed were not specifically modeled, their contributions are included in this project in the 10% other sources load estimate.

- SSOs

  Though SSOs occur episodically, they represent a high-risk vector for fecal bacteria contamination because they can have concentrations of fecal bacteria several orders of magnitude higher than treated effluent. Untreated sewage can contain large volumes of raw fecal waste, making it a significant health risk where SSOs are sizeable or chronic issues. Events are self-reported and may vary in quality. Descriptions of frequencies, causes, durations, and volumes of SSOs may be subject to logistical inadequacies such as unknown duration of discharge, and inability to accurately gauge discharge volume. Actual SSO volumes and incidences are generally expected to be greater than reported due to these fundamental challenges.

After reviewing data compiled in SSO reports submitted by permit holders in the East Fork San Jacinto River watershed[38], SSO events were not found to follow any specific spatial, seasonal, or annual pattern. Weather related events accounted for the highest number of events and overflow volume respective to the other general categories of weather, blockages, and unknown causes. Frequency of SSOs generally corresponded to volume of SSOs.

Due to the episodic nature and spatial inconsistency of SSO events, fecal bacteria loads from these sources are not expected to have an appreciable long-term impact on the overall loading for the watershed and were excluded from SELECT model analysis. Though the estimations of SSO impacts in this watershed are not represented by SELECT models, they are no less important to consider in the overall assessment of fecal bacteria loading. The most extreme method of estimating fecal bacteria loads from SSOs would be to calculate loading based on EPA literature values[39] suggested for general causes related to each event multiplied by the highest observed volumes of discharge recorded for each cause. A more conservative method would be to calculate the average daily volume of discharge and use that as the multiplier for cause related load estimates. In other area watershed projects, stakeholders elected to refrain from the aforementioned calculations and treat SSOs as a separate, high-priority item for inclusion in the management strategies outlined in the WPP. SSO data regarding unique events impacting stream segments within the watershed area over the most recent five years of reports provided by TCEQ were used in these assessments. East Fork San Jacinto River watershed stakeholders elected to adopt this method as well.

- **Human Waste – Direct Deposition**
  In other watershed projects, potential impacts from unhoused communities and areas not serviced by centralized or localized wastewater treatment were

[38] For more detail, see the Water Quality Data Analysis Summary Report on the project website at: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_3.2_acquired_data_analysis_report_final.pdf
[39] As referenced at: https://www3.epa.gov/npdes/pubs/csossoRTC2004_AppendixH.pdf

considered. Based on stakeholder feedback, the populations represented by these groups were not found to be large enough to have appreciable impact.

- Land Deposition of Sewage Sludge
  In the event that improper use of manure spreading or violations of sludge application have occurred in the watershed area, action would be required to intervene and reduce the resulting fecal bacteria loading impacts. No such activity is known in the East Fork San Jacinto River watershed; however, these impacts would likely be addressed in best management practices for agricultural sources of pollution.

- Concentrated Animal Feeding Operations (CAFO)s
  No active CAFOs are in operation within the East Fork San Jacinto River watershed.

- Birds
  The greater Houston area is well known as part of the great Central Flyway migration path used by various bird populations. Many migratory bird species only utilize the land area for short periods of time while in transit, but migratory waterfowl and resident species represent longer-term populations, especially in coastal marshes. Similar watershed projects have evaluated the potential impact of waterfowl in terms of duration, potential fecal bacteria load, and other considerations, and found them to not be significant sources to be modeled. Colonial birds such as swallows have been identified by other watershed projects as potential sources of fecal bacteria load. Unfortunately, little or no data is available to characterize the impacts of fecal bacteria loading from colonial bird sources or to implicate colonial bird influenced fecal bacteria loading as a significant health risks to the watershed community. Beyond lack of data, relatively small fecal bacteria loads and health risks associated with bird waste compared to human sources further reduce the significance of bird waste impacts. General lack of management strategies available to deal with wild birds have limited the emphasis of this source as a meaningful component of management efforts in similar projects.

- Bats
  Though bats are present in the watershed area, only large colonies of these animals are estimated to have an appreciable impact on water quality. No known nesting sites of significant size or density have been indicated in the East Fork San Jacinto River watershed.

- Other Sources

Specific data for wildlife such as coyotes, opossums, rodents, wild cats, skunks, raccoons, and other mammals is not widely available. Similar watershed projects have recognized these wildlife animals as potentially appreciable contributors to fecal bacteria loads but lacked a reasonable method for quantifying their potential impacts. One method of improving understanding of wildlife impacts in the East Fork San Jacinto River watershed would be to implement fecal bacteria source tracking or assessments of genetic material found in waterways to identify species depositing fecal waste in and around streams. Data collected with this method in other watersheds showed that wildlife impacts are significant[40] and should be incorporated into fecal bacteria reduction strategies. As no such data is presently available for the watershed area of East Fork San Jacinto River, the understanding of wildlife species in this watershed will be largely informed by anecdotal information provided by stakeholders and general estimations decided by stakeholder input. In nearby watershed projects on Cypress Creek and Spring Creek, a novel approach assumed wildlife impacts to be equivalent to a conservative 10% of the other modeled loads assessed in the watershed. The value was generated by finding the total for all other sources in all subwatersheds, setting that total as 90% of the total load, and then assuming wildlife to be the other 10%. The stakeholders of the East Fork San Jacinto River watershed also elected to employ this method. However, to reflect the likelihood of loss of wildlife habitat as development expands in the watershed, stakeholders opted not to assume a consistent additional 10% contribution from wildlife in projections for 2025 onward. Rather, the 2022 10% calculated value was repeated in all subsequent projections. Stakeholders reviewed these results and agreed that other wildlife are an important component of bacteria loading in East Fork San Jacinto River but were reluctant to attribute a firm percentage to their influence. However, recognizing that other sources with little data for quantification estimates are at play in this watershed, stakeholders opted to retain this 10% addition to the total estimated load and refer to it more generally as other sources.

- **Cats**

  Domestic dogs are included in the SELECT model analysis as a concern of particular interest to the watershed due to the likelihood of improperly managed dog waste deposited outdoors making its way to streams via runoff. Domestic

[40] For example, bacteria source tracking completed by Texas A&M University for Attoyac Bayou showed *E. coli* from wildlife at greater than 50% of load across flow conditions (https://oaktrust.library.tamu.edu/handle/1969.1/152424) and a similar analysis (https://oaktrust.library.tamu.edu/handle/1969.1/149197) conducted for the Lampasas and Leon Rivers showed comparable results.

cat waste management is typically handled indoors and restricted to litter boxes. Therefore, pet wastes from cats were not estimated as part of this project. Feral cats, however, can be a local source when found in sufficiently dense urban populations, though very little data exists to quantify these impacts. Generally, impacts from feral cats may be accounted for in other loading assumptions such as diffuse urban stormwater or as part of the impacts from other wildlife.

- **Dumping**
  Illegal dumping is not typically a widespread or appreciable contributor to fecal bacteria loads in watersheds as these events occur locally or episodically. This factor will still be important for stakeholders to consider addressing in the WPP in terms of aesthetic and other regulatory issues.

### Summary of *E. coli* Source Modeling Results

SELECT analyses indicated the highest loads from the total mix of modeled sources are concentrated in the Winters Bayou subwatershed because of pressures from agriculture and invasive feral hogs (**Table 24**). There is also a pronounced concentration of loading in the Lower East Fork San Jacinto River subwatershed associated with pressures related to development, including dog waste and OSSF discharge. Results shown in **Table 24** indicate the estimated current potential loads for all sources by subwatershed. Projected potential load in increments of five years by source are shown in **Table 25**. Assuming no additional action, changes in total load between 2022 and 2050 are shown in **Figure 29**. The year 2040, was set as an *E. coli* reduction milestone/target year and is therefore a different color than the other bars in the graph. Relative changes in source contributions between current and future conditions are shown in **Figure 30** and **Figure 31** respectively.

Without taking action to reduce fecal bacteria sources in the watershed, loads will continue to increase between 2022 and 2050. Noticeable changes in source load contributions between current conditions and those projected for 2050 involve decreased impacts from feral hogs relative to the expansion of sources associated with human development.

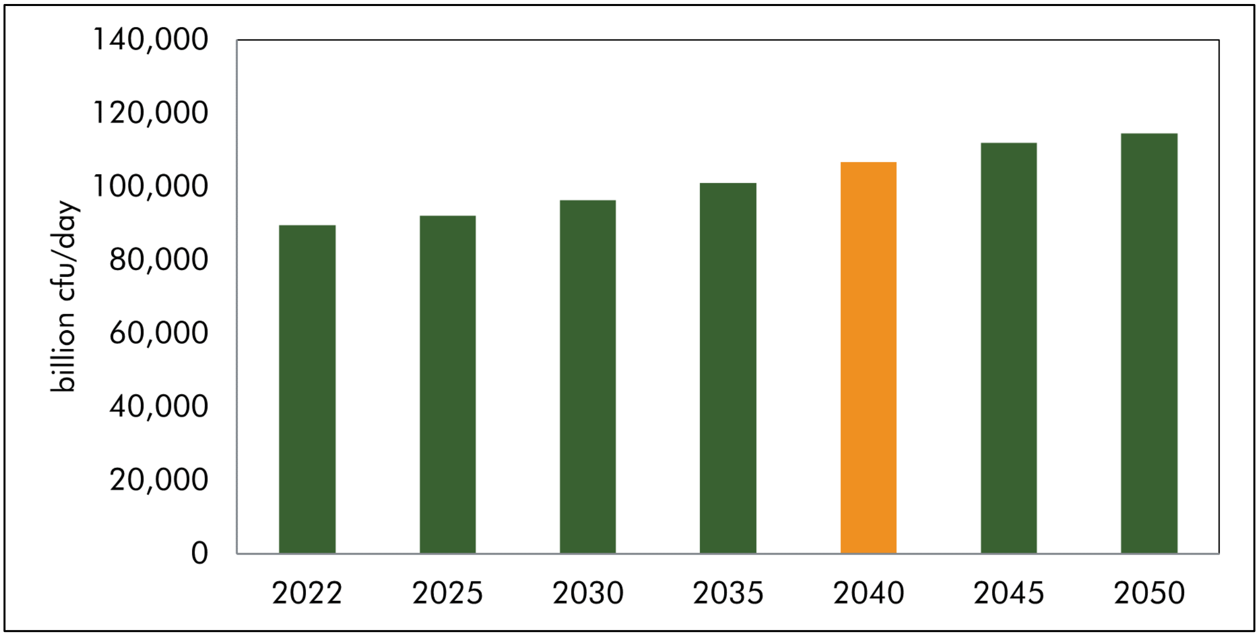


**Figure 29.** Potential total *E. coli* loads, with no action, 2022 to 2050

**Table 24.** Current *E. coli* loadings in billion cfu/day by source and subwatershed

| Source | Lower East Fork SJR (SW1) | Middle East Fork SJR (SW2) | Upper East Fork SJR (SW3) | Winters Bayou (SW4) | Nebletts Creek (SW5) | Boswell Creek (SW6) | % Total Load |
|---|---|---|---|---|---|---|---|
| OSSFs | 826.20 | 197.50 | 116.01 | 135.68 | 13.82 | 1.21 | 2% |
| WWTFs | 1.18 | 1.56 | 0.05 | 0.98 | 0.00 | 0.00 | 0% |
| Dogs | 3,244.20 | 1,062.30 | 395.40 | 474.00 | 67.50 | 4.20 | 6% |
| Cattle | 4,014.60 | 7,634.21 | 12,011.89 | 27,715.59 | 606.06 | 1,824.61 | 60% |
| Horses | 23.97 | 13.67 | 53.18 | 49.61 | 1.08 | 3.27 | 0% |
| Sheep & Goats | 376.04 | 715.08 | 1,125.12 | 2,596.04 | 56.77 | 170.91 | 6% |
| Deer | 47.60 | 66.03 | 99.58 | 132.14 | 7.83 | 27.63 | 0% |
| Other Sources | 1,862.77 | 2,550.32 | 3,729.85 | 5,193.07 | 289.77 | 986.48 | 16% |
| Feral Hogs | 1,155.17 | 1,360.07 | 1,947.90 | 4,033.01 | 115.87 | 335.37 | 10% |
| Total | **11,551.73** | **13,600.74** | **19,478.98** | **40,330.12** | **1,158.70** | **3,353.68** | **100%** |

**Table 25.** *E. coli* loadings in billion cfu/day by source for all milestone years

| Source | 2022 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| OSSFs | 1,290.42 | 1,368.13 | 1,585.78 | 1,992.10 | 2,714.63 | 3,380.01 | 3,685.21 |
| WWTFs | 3.77 | 3.95 | 4.56 | 5.52 | 6.71 | 7.49 | 7.86 |
| Dogs | 5,247.60 | 5,581.20 | 6,541.20 | 8,265.60 | 11,144.10 | 13,762.80 | 14,931.90 |
| Cattle | 53,806.96 | 55,931.68 | 58,619.53 | 60,994.68 | 63,037.11 | 64,823.72 | 65,864.98 |
| Horses | 144.78 | 148.16 | 152.33 | 156.01 | 159.38 | 162.33 | 163.96 |
| Sheep/ Goats | 5,039.95 | 5,238.96 | 5,490.73 | 5,713.20 | 5,904.51 | 6,071.86 | 6,169.39 |
| Deer | 380.82 | 381.75 | 382.80 | 383.82 | 385.00 | 386.24 | 386.55 |
| Feral Hogs | 14,612.26 | 14,569.80 | 14,522.72 | 14,481.30 | 14,445.77 | 14,414.28 | 14,395.12 |
| Other Sources | 8,947.39 | 8,947.39 | 8,947.39 | 8,947.39 | 8,947.39 | 8,947.39 | 8,947.39 |
| | 89,473.95 | 92,171.02 | 96,247.04 | 100,939.62 | 106,744.60 | 111,956.12 | 114,552.36 |

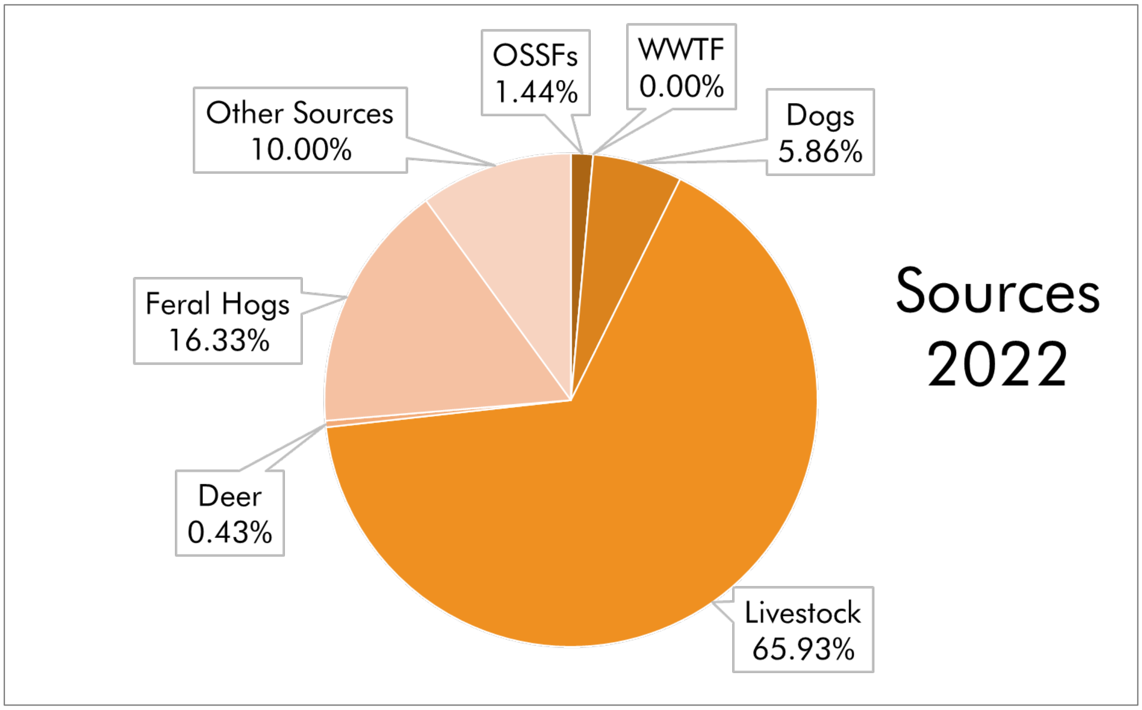


**Figure 30**. *E. coli* source profile, 2022

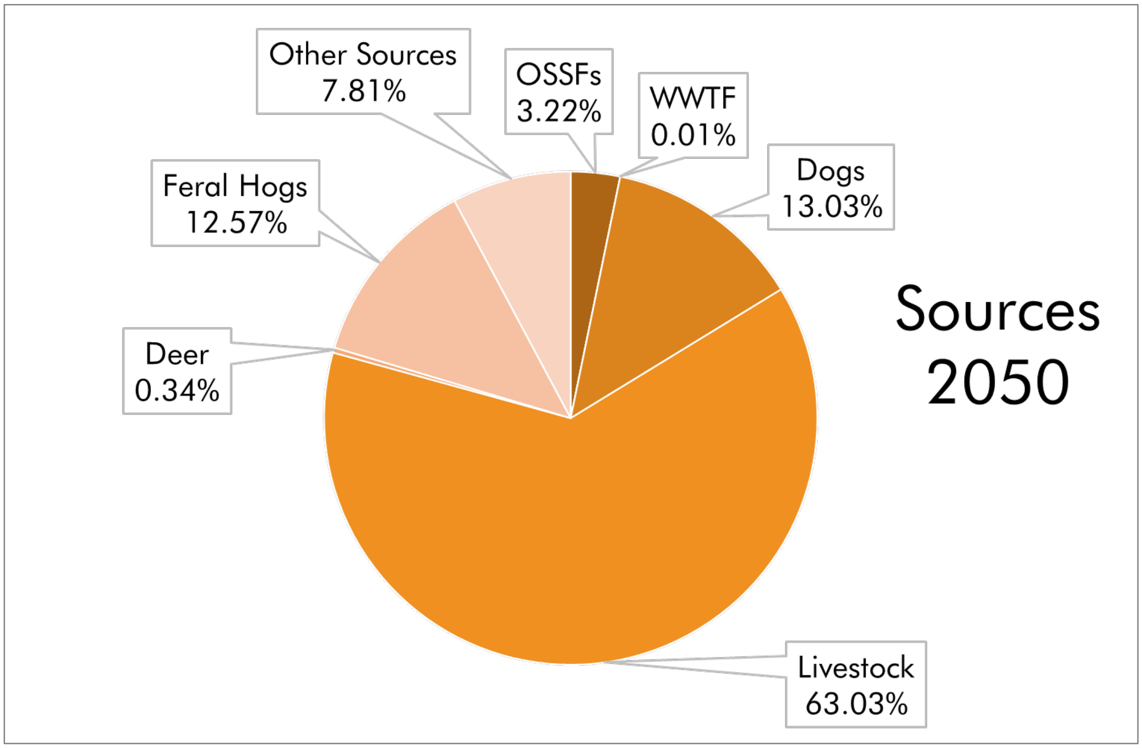


**Figure 31**. *E. coli* source profile, 2050

## Implications of Fecal Waste Source Characterization Findings

The results of LDC and SELECT models generated for this report indicate different fecal bacteria reduction needs for different areas of the watershed dictated by a complex mix of sources which are predicted to shift in coming years. Among these sources, livestock waste was determined to be the dominant pollutant in both current and projected scenarios. The increasing loads highlight the need for intervention through the WPP and other means. Current water quality issues will be compounded by future loads, leading to degrading water quality through the planning period absent any effort to the contrary.

Uncertainty is present throughout the assumptions and methodologies of this modeling approach, as noted throughout this document. Project staff used the best available data and stakeholder feedback to minimize uncertainty wherever possible, but the results should be taken in the context of their use in characterizing fecal waste pollution on a broad scale, and for scaling and siting BMPs. For these purposes, the level of uncertainty and precision of the results was deemed to be acceptable by the stakeholders. Further refinement of results may be needed in the future considering changing conditions. While bacteria source tracking or other analyses quantifying host organism DNA instream were not a function of this project, it may be a consideration in the future to further characterize sources, identify location-specific challenges, and refine the linkage between source loads and instream conditions.

## Other Concerns

No specific modeling was conducted for other stakeholder concerns such as flooding, or trash. However, stakeholder feedback was taken on problem areas, and project staff developed recommendations for coordinating with partner efforts and programs overlapping these concerns as part of the recommended solutions of this WPP.

### Trash

While no sites of appreciable concern were designated by stakeholders, trash in the waterway was considered as a concern, especially in denser urban areas of the downstream watershed, where trash enters through stormwater and sheet flow. Project staff identified ongoing efforts in the watershed that would be important points of coordination, with the intent of including trash in water quality conversations, and vice versa.

### Flooding

The potential use of natural infrastructure as supplement to flood mitigation projects, the conservation of open space, and the inclusion of water quality concerns in flood project design were all areas of needed coordination during the implementation of this WPP.