SECTION 4
RESULTS AND DISCUSSION

Ambient water sampling for this project lasted approximately 2 years - beginning on July 8, 2002 and ending July 27, 2004. Due to a lack of rain, the planned data collection was not achieved at many sites. At some sites, such as Bear Canyon Arroyo, Paseo del Norte Pump Station, Boca Negro Arroyo at Tesuque Road, and Adobe Acres Pump Station (Figures 4.1, 4.2, 4.3, and 4.4, respectively) runoff water was seldom or never observed. This was considered likely to be due to the small watershed size draining to these sites, high soil perviousness of the watershed reducing runoff, and the short duration of rainfall and runoff in these areas. Another factor may have been the relatively long driving distance from Parsons' office or the homes of sampling personnel to these sites. Upon observation of rainfall, often by the time the site was reached the runoff had passed. Finally, efforts to use automatic samplers to collect water samples at these sites were unsuccessful.

Figure 4.1 Bear Canyon Arroyo above High Desert Subdivision Looking East

Figure 4.2 Paseo del Norte Pump Station

Figure 4.3 Boca Negra Arroyo at Tesuque Road Looking East

Figure 4.4 Adobe Acres Pump Station Looking West

To make up for the samples not obtained at some sites, additional samples were collected at other sites where runoff was more frequently observed. Table 4.1 summarizes the actual number of ambient water samples collected under runoff and non-runoff conditions as compared to the target number of ambient samples proposed at the start of the project. Additionally, some samples were collected in February and March 2004 under dry, base flow conditions at the eight Rio Grande sites, the North Diversion Channel, and the South Diversion Channel. Finally, upon discovery that MEI never received a number of fecal coliform plates from Assaigai Analytical Laboratory, additional runoff water samples were collected in July 2004 to make up for these misplaced samples.

Table 4.1 Summary of Ambient Water Sampling

Sampling Site	Planned Ambient Samples	Collected Ambient Samples	
		Runoff	Non-runoff
1. Rio Grande at Angostura Diversion Dam	10	10	4
2. Rio Grande at Highway US 550	5	7	4
3. Rio Grande above Rio Rancho Utility #3	5	7	4
4. Rio Grande above Rio Rancho Utility #2	5	6	4
5. Rio Grande at Alameda Bridge	5	9	4
6. Rio Grande at Rio Bravo Bridge	5	7	3
7. Rio Grande at I-25	5	8	3
8. Rio Grande at Isleta Diversion Dam	10	11(2)	3
9. North Diversion Channel at Roy	5	9	3
10. North Domingo Baca Arroyo Dam at Primary Spillway	5	5 (1)	0
11. North Pino Arroyo above North Diversion Channel	5	11	0
12. Hahn Arroyo above North Diversion Channel at Carlisle	5	9	0
13. Embudo Channel above North Diversion Channel	5	9	0
14. Bear Canyon Arroyo above High Desert Subdivision	5	0	0
15. South Diversion Channel above Tijeras Arroyo	5	7	2
16. Sandia Pueblo Natural Arroyo at I-25	5	3	0
17. Paseo del Norte Pump Station	5	1	0
18. Alameda Drain at Ranchitos Road	5	7	0
19. Alameda Drain at El Caminito	5	7	0
20. Ranchitos de Albuquerque Storm Drain	5	4	0
21. Cabezon Channel	5	5	0
22. Calabacillas Arroyo at Swinburne Dam	5	2	0
23. Calabacillas Arroyo at Coors Road	5	4	0
24. Boca Negro Arroyo at Tesuque Road	5	1	0
25. San Antonio Arroyo at Rio Grande (Montano) Oxbow	5	3	0
26. Amole del Norte Channel above Amole Dam	5	2	0
27. Adobe Acres Pump Station	5	0	0
28. Vito Romero Pump Station	5	1	0
29. Los Padillas Drain just upstream of the Isleta Drain	5	8 (1)	0
30. Isleta Drain just upstream of the Los Padillas Drain	5	9	0
Grand Total	**160**	**172**	**34**

Number in parentheses represents duplicate samples.

4.1 Quality Assurance/Quality Control Results

Blanks and Duplicates

Bottle and equipment blanks were run with each group of samples delivered to the laboratory at the same time. All bottle and equipment blanks were negative for fecal coliform, reflecting a lack of contamination.

Field blanks were run at an average rate of one for every 12 samples. These blanks are run by collecting sterile water in the same manner as an ambient water sample, at the sampling location, and between ambient water samples. Thus, they incorporate potential contamination from all sources. Fourteen (82%) of the 17 field blank samples showed no contamination from fecal coliform bacteria. Two field blanks in July 2002 showed a single fecal coliform bacteria, but because this was less than 2 percent of the fecal coliform concentration in corresponding ambient water samples, this level of contamination met QC requirements. One field blank sample in August 2002 showed substantial contamination, with a fecal coliform concentration almost 25 percent of the lowest fecal coliform level of the associated ambient water samples. These water samples were not submitted for ribotyping and ARA due to the potential for effects from cross-sample contamination, and field staff were re-educated on procedures to prevent contamination. After August 2002, no contamination was observed in any field blank sample.

The analysis of field duplicates at the Rio Grande at Isleta Diversion Dam sample site yielded unclear results. Field duplicate samples were collected on only four dates due to staff error. Overall, 34 duplicate isolates were ribotyped, including as many as 5 for which sources were not identified. The sources of 18 (62%) of these isolates matched those of the respective duplicate samples, which was below the project objective of 75 percent. This may indicate the wide variety of contributing sources of fecal coliform observed at this site, with no dominant source. It may also be due, in part, to the fact that the number of *E. coli* ribotyped from many of the duplicate filters for each pair of samples was far from equal. Finally, the disagreement is likely due partially to the smaller than planned number of duplicate samples and isolates.

Precision and Accuracy

Ribotyping was extremely precise and repeatable. As stated earlier, MEI analyzed 300 unknown *E. coli* cultures. These 300 cultures represented three copies each of 100 different *E. coli* isolates cultures provided by MEI to the Parsons QA Officer (QAO) from the MEI known source library of *E. coli* isolates. These isolates included cultures from dogs, humans, cattle, seagulls, and sewage. Labels on the slant tubes containing the isolates were removed and replaced by the Parsons QAO with a randomly assigned number label (after making a key linking the MEI label number to the new label) before being returned to MEI. Thus, MEI could not identify the cultures except through ribotyping.

For each of the 300 unknown *E. coli* tested, MEI assigned the same ribotype ID to each of the three copies of a given isolate. In other words, with repeated analysis, the method produced the same ribotype result each time; thus, precision of the method was judged to be 100 percent.

Accuracy was judged by the ability of the lab to assign the correct ribotype ID to the unknown cultures. MEI assigned the correct ID to 94 percent of the unknown cultures. It should be noted that in most cases where the ribotype ID was incorrectly identified, the source species identified was actually correct. These precision and accuracy rates met the accuracy and precision DQOs of the project, and indicate that the ribotyping method used is a highly precise and accurate method with sufficient power to resolved differences in source ribotypes.

Sampling Representativeness

It is difficult to quantitatively assess the representativeness of actual conditions by the sampling effort. The representativeness of sampling was affected by severe drought conditions, by an unexpected lack of runoff at some sites, by contamination and lab errors that caused a loss of data, and other factors.

The severe drought conditions caused the sampling effort to be extended over more than 2 years, including parts of three summer monsoon seasons, which probably increased the representativeness of the sampling effort compared to the shorter period planned.

The lack of runoff water reduced the sample collection at some sites, which increased the uncertainty in identifying the sources of fecal pollution at those sites. However, this was balanced by additional sample collection at other sites where water was more frequently available. Because the sites where sampling was increased tended to be those with larger drainage areas, representing large portions of the watershed, the representative of overall conditions in the MRG watershed may have been increased. Some data were lost due to contamination and errors. Contamination of field blanks caused invalidation of data for a few samples. Overall, the sampling effort adequately represented ambient conditions in the MRG watershed during the study period.

4.2 Fecal Coliform Levels in Water

An urban influence on levels of fecal coliform bacteria was observed in the Rio Grande under runoff conditions, with river reaches in Sandoval County often substantially lower than those in Bernalillo County (Table 4.2). The geometric mean fecal coliform levels in the Rio Grande increased from 341 at Angostura Diversion Dam to 4,610 at the Interstate 25 bridge south of Albuquerque, before declining at Isleta Diversion Dam. The North Diversion Channel, with a geometric mean of almost a 100,000 fecal coliform level under runoff conditions, may serve as the primary factor causing the increase in Rio Grande fecal coliform levels between the Angostura Diversion Dam and Isleta Diversion Dam.

Among the various arroyos and storm drains monitored, the highest levels of fecal coliform were typically found in the North Diversion Channel and several of the arroyos draining to it, including Hahn Arroyo, Embudo Arroyo, North Domingo Baca Arroyo, and to a lesser extent, the North Pino Arroyo. These arroyos drain some of the most populated portions of the watershed. Runoff from the North Diversion Channel drainage may explain the large increase in fecal coliform levels in the Rio Grande between Rio Rancho Utility #2 and the Alameda Bridge. Fecal coliform levels in the South Diversion Channel tended to be much lower than those in the North Diversion Channel under runoff conditions.

On the west bank of the Rio Grande, high fecal coliform levels in runoff were observed in San Antonio Arroyo and Amole del Norte Channel, although the number of samples was small. Isleta and Los Padillas Drains present an interesting contrast. Although they drain adjacent watersheds, the levels of fecal coliform in the Isleta Drain were on average an order of magnitude higher than those in Los Padillas Drain after rainfall. The factors responsible for this difference are difficult to discern. The Isleta Drain watershed has substantially less developed land and cropland as a fraction of total land area, and while the Isleta Drain watershed has a higher human population, its population density is actually less than that of Los Padillas Drain. The Isleta Drain also has a lower density of septic tanks and a higher percentage of households served by public sewer. One possible explanation for the higher fecal coliform levels in the Isleta Drain is that the return from a lateral irrigation ditch enters the Isleta Drain just above the sampling point.

Among the sites with four or more samples, a rank correlation test revealed that the geometric mean fecal coliform levels were strongly related to the human population density of the watershed (Spearman's rho=0.75, α=0.0001). Fecal coliform levels were inversely related to cropland density and household agricultural income, and not significantly related to septic tank density, indicating that agricultural sources and septic tank malfunctions may not be major sources of fecal coliform in runoff.

In dry weather, fecal coliform levels at all Rio Grande sites, as well as the North and South Diversion Channels, were typically low and met WQSs (Table 4.3). This is consistent with historical observations. Under base flow conditions, the Rio Grande sites exhibited a pattern of increasing fecal coliform levels with distance downstream, peaking at the Interstate 25 bridge, similar to that observed under runoff conditions. This may indicate that the sources of fecal coliform are similar in dry and wet weather, even though the magnitude is much different. Table 4.2 does not include fecal counts for site number 14, Bear Canyon Arroyo above High Desert Subdivision, and site 27, Adobe Acres Pump Station, because no ambient water quality data were collected at these sites as indicated in Table 4.1.

Table 4.2 Summary of Ambient Fecal Coliform Levels under Runoff Conditions

Site Number	Site Name	Number of Samples	Mininum[1]	Maximum[1]	Geometric Mean[1]
1	Rio Grande at Angostura Diversion Dam	10	27	36,000	341
2	Rio Grande at Highway US 550	7	45	29,000	354
3	Rio Grande above Rio Rancho Utility #3	7	54	34,000	657
4	Rio Grande above Rio Rancho Utility #2	6	63	1,820	362
5	Rio Grande at Alameda Bridge	9	45	38,000	1,630
6	Rio Grande at Rio Bravo Bridge	7	64	650,000	2,320
7	Rio Grande at I-25	8	490	360,000	4,610
8	Rio Grande at Isleta Diversion Dam	11	360	38,000	2,160
9	North Diversion Channel at Roy	9	2,800	1,040,000	95,900
10	North Domingo Baca Arroyo Dam at Primary Spillway	5	25,000	110,000	63,600
11	North Pino Arroyo above North Diversion Channel	11	631	>600,000	17,500
12	Hahn Arroyo above North Diversion Channel at Carlisle	9	1,080	530,000	97,500
13	Embudo Channel above confluence with	9	1,610	>600,000	76,300

Site Number	Site Name	Number of Samples	Mininum[1]	Maximum[1]	Geometric Mean[1]
	North Diversion Channel				
15	South Diversion Channel above Tijeras Arroyo	7	189	800,000	7,090
16	Sandia Pueblo Natural Arroyo at I-25	3	3,700	200,000	22,500
17	Paseo del Norte Pump Station	1	900	900	900
18	Alameda Drain at Ranchitos Road	7	851	51,000	5,470
19	Alameda Drain at El Caminito	7	712	36,000	8,180
20	Ranchitos de Albuquerque Storm Drain	4	1,710	80,000	18,000
21	Cabezon Channel	5	742	70,000	3,140
22	Calabacillas Arroyo at Swinburne Dam	2	270	60,000	4,020
23	Calabacillas Arroyo at Coors Road	4	200	800,000	18,400
24	Boca Negro Arroyo at Tesuque Road	1	7,270	7,270	7,270
25	San Antonio Arroyo at Rio Grande (Montano) Oxbow	3	3,000	200,000	39,100
26	Amole del Norte Channel above Amole Dam	2	20,000	80,000	40,000
28	Vita Romero Pump Station	1	2,600	2,600	2,600
29	Los Padillas Drain just upstream of the confluence with the Isleta Drain	8	36	2,600	253
30	Isleta Drain just upstream of the confluence with Los Padillas Drain	9	200	420,000	2,110
	Grand Total	172	27	1,040,000	4,970

[1] cfu/100 mL

Table 4.3 Summary of Ambient Fecal Coliform Levels under Non-Runoff Conditions

Station Number	Station Name	Number of Samples	Mininum[1]	Maximum[1]	Geometric Mean[1]
1	Rio Grande at Angostura Diversion Dam	4	<10	18	6
2	Rio Grande at Highway US 550	4	<10	63	7
3	Rio Grande above Rio Rancho Utility #3	4	<10	54	13
4	Rio Grande above Rio Rancho Utility #2	4	<10	27	12
5	Rio Grande at Alameda Bridge	4	9	36	20
6	Rio Grande at Rio Bravo Bridge	3	9	135	22
7	Rio Grande at I-25	3	189	684	412
8	Rio Grande at Isleta Diversion Dam	3	36	350	119
9	North Diversion Channel at Roy	3	63	712	296
15	South Diversion Channel above Tijeras Arroyo	2	18	90	40
	Grand Total	34	<10	712	28

[1] cfu/100 mL

4.2.1 *E. coli* Counts Relative to Fecal Coliform

Of the fecal coliform colonies collected during the study, on average 70 percent were positively identified as *E. coli*. For samples collected in runoff conditions, 65 percent of fecal coliform were identified as *E. coli*, while approximately 90 percent of the fecal coliform collected in dry weather were identified as *E. coli*.

4.2.2 Occurrence of Pathogenic Bacteria Strains

Forty-seven (2.9%) of the 1,635 *E. coli* isolated and purified from ambient water samples were hemolytic strains of *E. coli*. Hemolytic *E. coli* such as strain O157:H7, can cause serious illness in humans. These hemolytic *E. coli* were found in 29 water samples under runoff and non-runoff conditions from 15 sites, and thus generally were in low abundance compared to non-hemolytic strains in all samples. The ribotypes of these hemolytic bacteria indicated that 21 were resident in canine hosts, eight were from cats, seven were from human or sewage sources, five were avian-resident species, one each were from horse and rodent sources, and four were from unknown sources. As a percentage of *E. coli* by source, hemolytic *E. coli* were most abundant in canines (45%), cats (17%), humans (15%), and avian (11%). Only one hemolytic *E. coli* was observed in livestock-resident strains, and a few were also observed in wildlife-resident strains.

Nineteen *E. coli* bacteria from septage or sewage samples were also hemolytic, providing evidence of the hazard of human waste.

4.3 Identified Bacterial Sources Based on MST Technology

To interpret results of MST and summarize the fraction of fecal coliform in ambient water from specific sources, it is important to note that the relative weighting of individual water samples in the source summary are not equal. There are many reasons for this unequal weighting related to the sampling and analytical process. The primary reasons include:

- the number of water samples collected from each site was variable;
- the number of discrete fecal coliform colonies that could be harvested by MEI from a filter varied from 0 to more than 100;
- the fraction of fecal coliform colonies harvested from a filter that, upon purification and testing, were found not to be *E. coli* varied from 0 to 100 percent; and
- discretion of the laboratory staff. In some cases, fecal coliform plates were re-sampled to harvest additional colonies.

It is notable that the number of satisfactory ribotypes obtained from a single water sample ranged from 0 to 44. Thus, when reporting and interpreting the data, the reader must understand that when computing summary statistics regarding source identification, one sample may have far more influence on the results than another. Science can attempt to normalize the results to reduce this disparate influence, but because many factors control the sample influence, there are as many different possible ways to normalize. For this reason, Parsons provided the raw data in Appendix B to allow users to interpret data according to their needs.

4.3.1 Source Categories

The subjective grouping of ribotypes into source categories merits discussion. The categorization is based to some extent on the basis of biological similarity, but is also influenced by co-occurrence of species. For example, cattle and emu are not biologically similar, but these categories can be grouped as livestock that tend to occur on farms.

E. coli strains that have been observed in more than one source type are considered transient strains. Because they cannot be used to identify a source, the source of *E. coli* is identified as "unknown." *E. coli* isolated from water samples that do not match any *E. coli* in the known source library are also assigned to "unknown" sources.

When *E. coli* are observed in multiple species, but the species are closely related, they are not identified as transient strains, but the source category description is expanded. For example, strains that have been seen only in dogs and coyotes will be assigned to the category "canine," and strains observed in bison and cattle will be assigned to the category "bovine." There is a biological basis for this grouping, as the conditions in the gut of closely related species are expected to be similar, and gut conditions are believed to be one of the primary factors influencing which *E. coli* strains are abundant.

Resolution of the avian source to the species level does not appear practical with ribotyping at this time. The *E. coli* strains of the avian gut have been commonly found in many different bird species. However, some strains of *E. coli* are only seen in waterfowl. Thus, avian strains may be categorized as the more specific "waterfowl" or the less specific "avian," but no identification to species level can be made with confidence. As the size of the known source library grows, it is possible that more species-specific strains will be identified.

The category "human" is assigned to *E. coli* strains that have only been observed in human feces. Sewage, septage, and sewage sludge are assumed to consist primarily of human waste, but may also include fecal matter from other domestic and livestock species. When source categories are grouped into "supercategories," Parsons grouped sewage, septage, and sludge with human sources.

Dogs, cats, and other non-native, non-livestock animals are grouped into the supercategory "pets." All native wild mammals, including rodents, coyotes, deer, *etc*., are grouped into the supercategory "non-avian wildlife." When categories include both wild and domestic species, they are included in the respective domestic supercategory totals because it is believed the abundance of the domestic species typically exceeds that of the wild species. For example, *E. coli* from the "canine" source category, which includes strains found in both dogs, coyotes, and wolves, are included in the supercategory "pets" rather than "non-avian wildlife."

The total number of *E. coli* ribotypes and ARPs from ambient water samples was somewhat below the planned total overall (1920 isolates), and at many specific sites (Table 4.4). The high number of *E. coli* at some sites was due in part from a lack of water samples at many sites, to low sample fecal coliform concentrations at other sites (*e.g*., Rio Grande at Angostura), and an abundance of non-*E. coli* fecal coliforms at other sites. The number of isolates typed will affect the uncertainty in source estimates. The uncertainty of the source estimate will be reported as a 95 percent confidence interval.

Table 4.4 Summary of Ribotype and Antibiotic Resistance Profiles

Station	Planned Ambient Isolates	Valid Ambient Isolates Typed	
		Ribotype	ARA
1. Rio Grande at Angostura Diversion Dam	120	41	44
2. Rio Grande at Highway US 550	60	67	79
3. Rio Grande above Rio Rancho Utility #3	60	82	91
4. Rio Grande above Rio Rancho Utility #2	60	89	93
5. Rio Grande at Alameda Bridge	60	119	130
6. Rio Grande at Rio Bravo Bridge	60	90	92
7. Rio Grande at I-25	60	152	167
8. Rio Grande at Isleta Diversion Dam	120	202	213
9. North Diversion Channel at Roy	60	106	109
10. North Domingo Baca Arroyo Dam at Primary Spillway	60	25	28
11. North Pino Arroyo above North Diversion Channel	60	58	59
12. Hahn Arroyo above North Diversion Channel at Carlisle	60	73	77
13. Embudo Channel above North Diversion Channel	60	75	79
14. Bear Canyon Arroyo above High Desert Subdivision	60	0	0
15. South Diversion Channel above Tijeras Arroyo	60	91	94
16. Sandia Pueblo Natural Arroyo at I-25	60	4	4
17. Paseo del Norte Pump Station	60	2	2
18. Alameda Drain at Ranchitos Road	60	56	45
19. Alameda Drain at El Caminito	60	36	41
20. Ranchitos de Albuquerque Storm Drain	60	7	24
21. Cabezon Channel	60	34	39
22. Calabacillas Arroyo at Swinburne Dam	60	19	21
23. Calabacillas Arroyo at Coors Road	60	23	23
24. Boca Negro Arroyo at Tesuque Road	60	0	0
25. San Antonio Arroyo at Rio Grande (Montano) Oxbow	60	0	0
26. Amole del Norte Channel above Amole Dam	60	24	24
27. Adobe Acres Pump Station	60	0	0
28. Vita Romero Pump Station	60	20	20
29. Los Padillas Drain just upstream of the Isleta Drain	60	79	86
30. Isleta Drain just upstream of the Los Padillas Drain	60	46	52
Grand Total	1920	1620	1736

4.3.2 Fecal Coliform Source Contribution Estimates Based on Ribotyping

In this section, fecal coliform source contributions are estimated for the watershed as a whole and for individual sampling sites with more than 10 *E. coli* as typed. There were seven sampling sites out of 30 that could not be evaluated for fecal coliform source contributions because they did not meet this threshold of having at least 10 *E. coli* isolates. Source contributions are calculated as the sum of isolates matching a particular source category or supercategory, divided by the total number of *E. coli* for which sources are identified. *E. coli* from unknown sources will not be included in the calculation because they may belong to any of the categories.

4.3.2.1 Middle Rio Grande Watershed as a Whole

Ribotype results indicate a variety of sources appear to contribute to the fecal coliform levels in the MRG watershed, as illustrated in Table 4.5 and Figure 4.5. Overall, the largest fraction of *E. coli* matched those found in avian sources, followed by canine, human/sewage, rodents, bovines, and equines. The source of approximately 9 percent of the *E. coli* could not be identified.

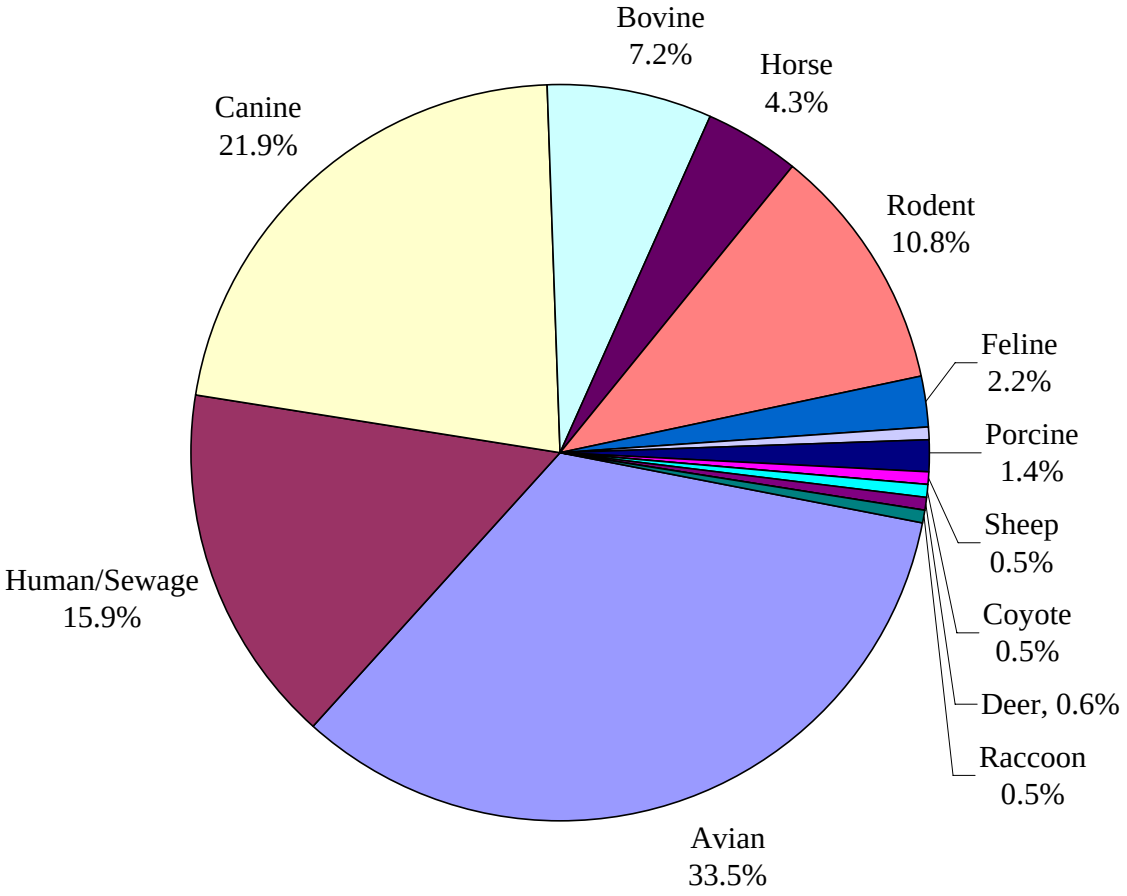
With the exception of rodents, only a few species of wild mammals were identified as sources of fecal coliform found in water: deer or elk, raccoon, coyote, bear, and opossum. It should be noted that an unknown fraction of the canine isolates may be from coyotes and foxes, as many *E. coli* strains are resident both in domestic dogs and wild canines.

Table 4.5 Fecal Source Estimate using Ribotyping for the Entire MRG Project Area

Category	Number of Isolates	% Source Contribution†	95% Confidence Interval
Human/ Sewage Subtotal	235	15.9 %	14.0 – 17.8 %
Bovine	106	7.2%	5.9 – 8.5 %
Equine	63	4.3%	3.3 – 5.3 %
Porcine	21	1.4%	0.8 – 2.0 %
Sheep	8	0.5%	0.1 – 0.9%
Goats	5	0.3%	0 – 0.6 %
Livestock Subtotal	203	13.7%	11.9 – 15.5 %
Avian Subtotal	496	33.5%	31.1 – 35.9 %
Canine	324	21.9%	19.8 – 24.0 %
Feline	33	2.2%	1.4 – 3.0 %
Canine & Feline Subtotal	357	24.1%	21.9 – 26.3 %
Rodent	164	10.8%	9.2 – 12.4 %
Deer & elk	9	0.6%	0.2 – 1.0 %
Coyote	7	0.5%	0.2 – 0.8 %
Raccoon	8	0.5%	0.1 – 0.9 %
Bear	1	0.1%	0 – 0.2%
Opossum	1	0.1%	0 – 0.2%
Non-Avian Wildlife Subtotal	190	12.8%	11.1 – 14.5 %
Unknown	139	8.6 %	7.2 – 9.9 %
Grand Total	1620		

† *Because the unknown isolates may have come from any of these categories, the 139 unknown isolates were ignored in calculating the % source contributions. In other words, the number of isolates of a source category were divided by the total isolates from all identified sources to calculate percentage source contributions*

Figure 4.5 Sources of *E. coli* in the Entire MRG Study Area Using Ribotyping



It should again be noted that the source apportionment in Table 4.5 is calculated from raw data, based on the number of *E. coli* isolates typed overall, including runoff and base flow samples. The unequal number of samples for each site and the number of isolates harvested from each sample may somewhat skew the results.

It is possible to normalize the results to attempt to remove the effect of the unequal isolate representation in the totals. One way to normalize the results involves weighting each isolate in the sum so each water sample has an equivalent weight in the source composition summaries. This is referred to as equal-sample weighting. One can additionally weight each isolate so that each site has an equivalent total weight of isolates contributing to the source composition summaries. This is referred to as equal-site weighting. The results of equal-sample and equal-site weighting are compared to the unweighted results in Table 4.6. It is apparent that equal-sample and equal-site weighting do not substantially change the source composition results. This is unexpected since the weights assigned to individual isolates differed by a factor of up to 50 for equal-sample weighting and up to 101 for equal-site weighting. The large number of samples collected and isolates characterized is one reason the weighting scheme does not greatly affect the results. Thus, even though some sites or samples are weighted very heavily relative to others, those samples still represent only a fraction of the total sample count. Another

reason is that the sources were somewhat consistent among sites and dates. As a result of this comparison, the unweighted results will be discussed for the remainder of this report.

Table 4.6 Comparison of Unweighted and Weighted Source Composition Estimates

Category	Number of Isolates	Equal-Isolate (Unweighted) % Contribution	Equal-Sample Weighted % Contribution	Equal-Site Weighted % Contribution
Human/Sewage Subtotal	229	15.9 %	15.2 %	14.0 %
Bovine	102	7.2%	11.1 %	6.3 %
Equine	61	4.3%	4.7 %	3.2 %
Porcine	21	1.4%	1.2 %	0.9 %
Sheep	8	0.5%	0.7 %	0.4 %
Goats	5	0.3%	0.2 %	0.3 %
Livestock Subtotal	197	13.7%	17.9 %	11.1 %
Avian Subtotal	473	33.5%	31.1 %	30.5 %
Canine	317	21.9%	22.4 %	28.5 %
Feline	33	2.2%	2.1 %	2.6 %
Canine & Feline Subtotal	350	24.1%	24.5 %	31.1 %
Rodent	155	10.8%	9.3 %	11.7 %
Deer & Elk	9	0.6%	0.7 %	0.5 %
Coyote	7	0.5%	0.2 %	0.3 %
Raccoon	8	0.5%	1.1 %	0.7 %
Bear	1	0.1%	0.03 %	0.02 %
Opossum	1	0.1%	0.03 %	0.04 %
Non-Avian Wildlife Subtotal	185	12.8%	11.4 %	13.3 %

Parsons also examined fecal sources under runoff influences and non-runoff, base flow conditions. As demonstrated in Table 4.7, it is apparent that the major sources are found under both conditions. The only differences in source contributions that were significantly different at the 95 percent confidence level were for the categories “canine” and “unknown.” Canines comprised a substantially smaller portion of the total sources under base flow conditions. *E. coli* from unknown sources were found to a greater extent under runoff conditions. Birds and human/sewage sources comprised a larger proportion of the total *E. coli* under base flow conditions, though the difference was not statistically significant. Further comparisons of sources under runoff and non-runoff conditions are provided for individual sites where 20 or more *E. coli* were typed from non-runoff water samples.

Table 4.7 Comparison of Sources under Runoff vs. Non-Runoff Conditions

Category	Runoff			Non-Runoff		
	Number of Isolates	% Contribution	95% Confidence Interval	Number of Isolates	% Contribution	95% Confidence Interval
Human/Sewage Subtotal	186	15.5 %	13.5–17.4 %	43	18.5 %	13.6–23.5 %
Bovine	86	7.2 %	5.8 – 8.5 %	16	6.9 %	3.7 – 10.1 %
Equine	53	4.4 %	3.3 – 5.5 %	8	3.4 %	1.1 – 5.8 %
Porcine	14	1.2 %	0.6 – 1.7 %	7	3.0 %	0.9 – 5.2 %
Sheep	7	0.6 %	0.2 – 1.0 %	1	0.4 %	0 – 1.3 %
Goats	5	0.4 %	0.1 – 0.8 %	0	0.0 %	0 – <1.3 %
Livestock Subtotal	165	13.7 %	11.9– 5.6 %	32	13.8 %	9.4 – 18.2 %
Avian Subtotal	383	31.9 %	29.4–34.4 %	90	38.8 %	32.6–45.0 %
Canine	286	23.8 %	21.5–26.1 %	31	13.4 %	9.1 – 17.7 %
Feline	25	2.1 %	1.3 – 2.8 %	8	3.4 %	1.1 – 5.8 %
Canine & Feline Subtotal	311	25.9 %	23.5–28.2 %	39	16.8 %	12.1–21.5 %
Rodent	130	10.8 %	9.0 – 12.6 %	25	10.8 %	6.9 – 14.7 %
Rabbit	4	0.3 %	0 – 0.6 %	0	0%	0 – <1.3 %
Deer & Elk	6	0.5 %	0.1 – 0.9 %	3	1.3 %	0 – 2.7 %
Coyote	7	0.6 %	0.2 – 1.0 %	0	0.0 %	0 – <1.3 %
Raccoon	8	0.7 %	0.2 – 1.1 %	0	0.0 %	0 – <1.3 %
Bear	1	0.1 %	0 – 0.2 %	0	0.0 %	0 – <1.3 %
Opossum	1	0.1 %	0 – 0.2 %	0	0.0 %	0 – <1.3 %
Non-Avian Wildlife Subtotal	157	13.1 %	11.2–14.9 %	28	12.1 %	7.9 – 16.2 %
Unknown	121	9.1 %	7.6 - 10.7 %	8	3.3 %	1.1 – 5.6 %
Total	1323			232		

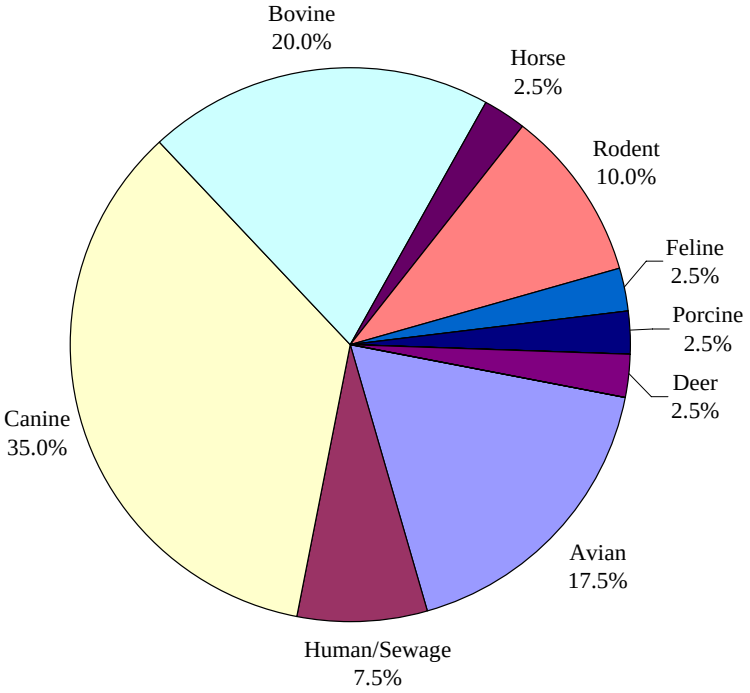
4.3.2.2 Rio Grande at Angostura Diversion Dam

The largest sources of fecal coliform at this site were canines - dogs, coyotes, and/or foxes. Cattle and birds were also major sources.

Table 4.8 Fecal Source Estimate for the Rio Grande at Angostura Diversion Dam

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	3	7.5 %	0 – 15.7 %
Bovine	8	20.0 %	7.6 – 32.4 %
Equine	1	2.5 %	0 – 7.3 %
Porcine	1	2.5 %	0 – 7.3 %
Livestock Subtotal	10	25 %	11.6 – 38.4 %
Avian Subtotal	7	17.5 %	5.7 – 29.3 %
Canine	14	35%	20.2 – 49.8 %
Feline	1	2.5 %	0 – 7.3 %
Canine & Feline Subtotal	15	37.5 %	22.5 – 52.5 %
Rodent	4	10 %	0.7 – 19.3 %
Deer & elk	1	2.5 %	0 – 7.3 %
Non-Avian Wildlife Subtotal	5	12.5 %	2.3 – 22.7 %
Unknown	1	2.4 %	
Grand Total	41		

Figure 4.6 Sources of *E. coli* at Rio Grande at Angostura Diversion Dam



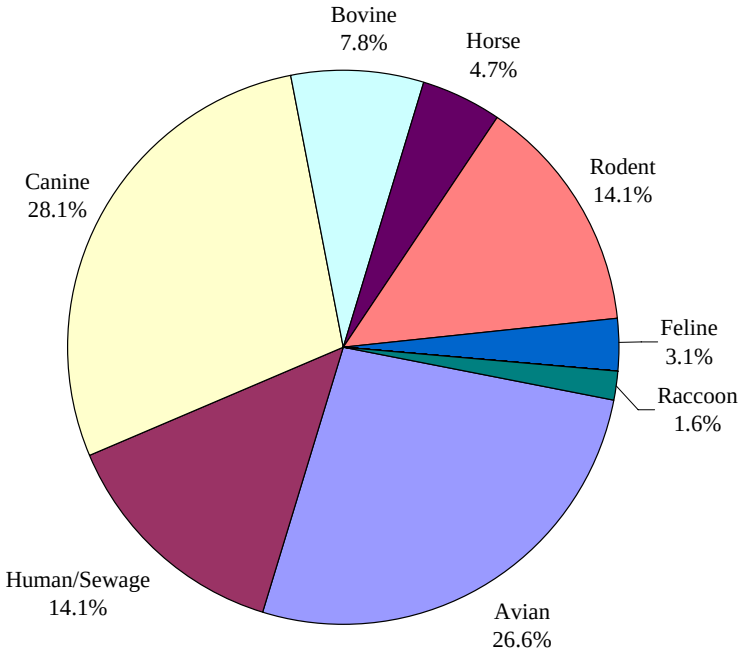
4.3.2.3 Rio Grande at Highway US 550

Canines and birds represented the largest source of fecal coliform at this site.

Table 4.9 Fecal Source Estimate for the Rio Grande at Highway US 550

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	9	14.1 %	5.6 – 22.6 %
Bovine	5	7.8 %	1.2 – 14.4 %
Equine	3	4.7 %	0 – 9.9 %
Livestock Subtotal	8	12.5 %	4.4 – 20.6 %
Avian Subtotal	17	26.6 %	15.8 – 37.4 %
Canines	18	28.1 %	17.1 – 39.1 %
Feline	2	3.1 %	0 – 7.4 %
Canine & Feline Subtotal	20	31.3 %	19.9 – 42.7 %
Rodent	9	14.1 %	5.6 – 22.6 %
Raccoon	1	1.6 %	0 – 4.6 %
Non-Avian Wildlife Subtotal	10	15.6 %	6.7 – 24.5 %
Unknown	3		
Grand Total	67		

Figure 4.7 Sources of *E. coli* at Rio Grande at Highway US 550



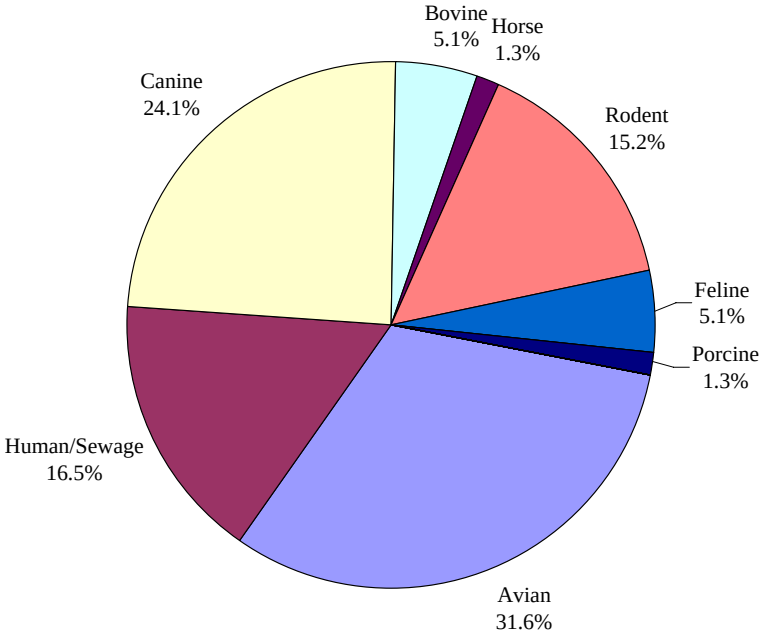
4.3.2.4 Rio Grande above Rio Rancho Utility #3

Birds and canines again represented the largest source of fecal coliform at this site.

Table 4.10 Fecal Source Estimate for the Rio Grande above Rio Rancho Utility #3

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	13	16.5 %	8.3 – 24.7 %
Bovine	4	5.1 %	0.9 – 9.3 %
Equine	1	1.3 %	0 – 3.8 %
Porcine	1	1.3 %	0 – 3.8 %
Livestock Subtotal	6	7.6 %	1.8 – 13.4 %
Avian Subtotal	25	31.6 %	21.3 – 41.9 %
Canines	19	24.1 %	14.6 – 33.5 %
Feline	4	5.1 %	0.3 – 9.9 %
Canine & Feline Subtotal	23	29.2 %	19.2 – 39.2 %
Rodent	12	15.2 %	7.3 – 23.1 %
Non-Avian Wildlife Subtotal	12	15.2 %	7.3 – 23.1 %
Unknown	3		
Grand Total	82		

Figure 4.8 Sources of *E. coli* at Rio Grande above Rio Rancho Utility #3



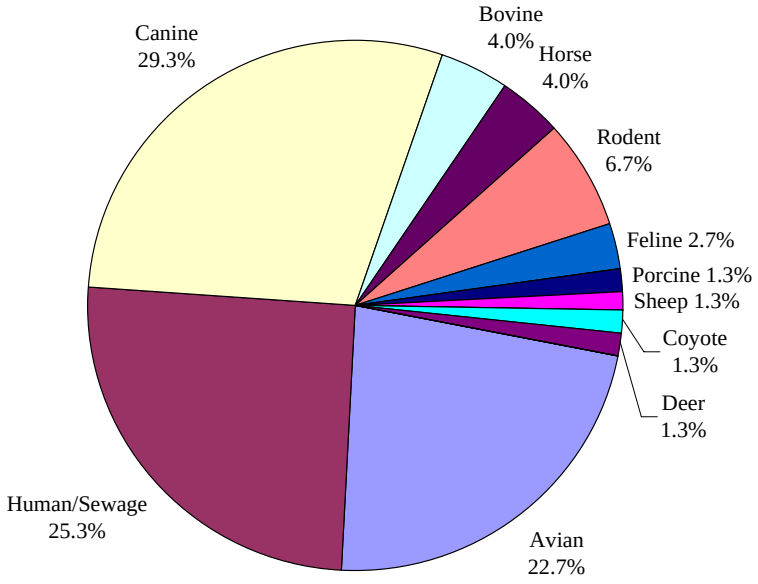
4.3.2.5 Rio Grande above Rio Rancho Utility #2

There was a significant increase in fecal coliform at this site from human/sewage sources; however, canine species again were the largest source of fecal coliform contribution.

Table 4.11 Fecal Source Estimate for the Rio Grande above Rio Rancho Utility #2

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	19	25.3 %	15.5 – 35.1 %
Bovine	3	4.0 %	0- 8.4 %
Equine	3	4.0 %	0- 8.4 %
Porcine	1	1.3 %	0 – 3.8 %
Sheep	1	1.3 %	0 – 3.8 %
Livestock Subtotal	8	10.7 %	3.7 – 17.7 %
Avian Subtotal	17	22.7 %	13.2 – 32.2 %
Canines	22	29.3 %	19.0 – 39.6 %
Feline	2	2.7 %	0 – 6.3 %
Canine & Feline Subtotal	24	32.0 %	21.4 – 42.6 %
Rodent	5	5.3 %	0.2 – 10.5 %
Deer & elk	1	1.3 %	0 – 3.8 %
Coyote	1	1.3 %	0 – 3.8 %
Non-Avian Wildlife Subtotal	7	9.3 %	2.7 – 15.9 %
Unknown	14		
Grand Total	89		

Figure 4.9 Sources of *E. coli* at Rio Grande above Rio Rancho Utility #2



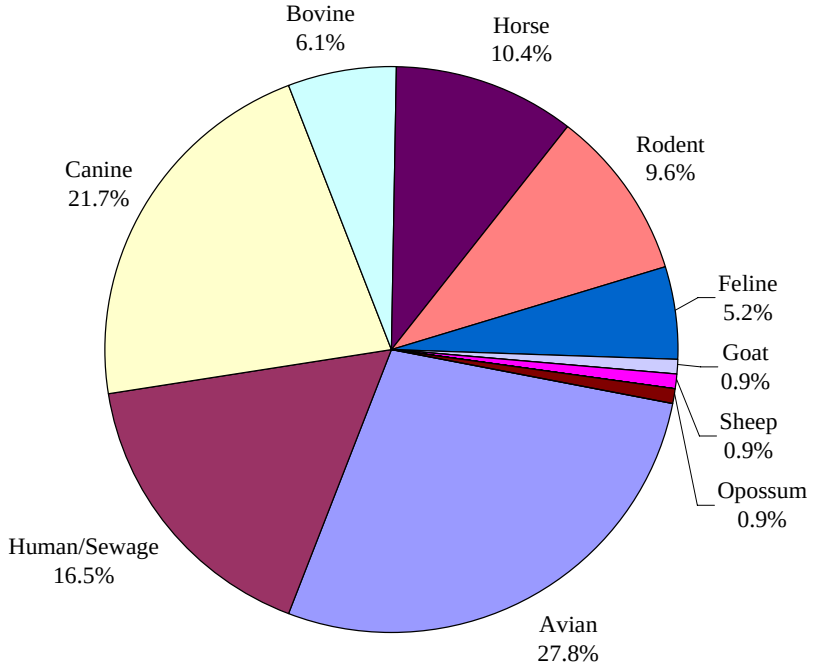
4.3.2.6 Rio Grande at Alameda Bridge

Birds and canines again represented the largest source of fecal coliform at this site.

Table 4.12 Fecal Source Estimate for the Rio Grande at Alameda Bridge

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	19	16.5 %	9.7 – 25.3 %
Bovine	7	6.1 %	2.0 – 10.2 %
Equine	12	10.4 %	4.8 – 16.0 %
Sheep	1	0.9 %	0 – 2.6 %
Goats	1	0.9 %	0 – 2.6 %
Livestock Subtotal	21	18.3 %	11.2 – 25.4 %
Avian Subtotal	32	27.8 %	19.6 – 36.0 %
Canines	25	21.7 %	14.2 – 29.2 %
Feline	6	5.2 %	1.1 – 9.3 %
Canine & Feline Subtotal	31	27.0 %	18.9 – 36.1 %
Rodent	11	9.6 %	4.2 – 15.0 %
Opossum	1	0.9 %	0 – 2.6 %
Non-Avian Wildlife Subtotal	12	10.4 %	4.8 – 16.0 %
Unknown	4		
Grand Total	119		

Figure 4.10 Sources of *E. coli* at Rio Grande at Alameda Bridge



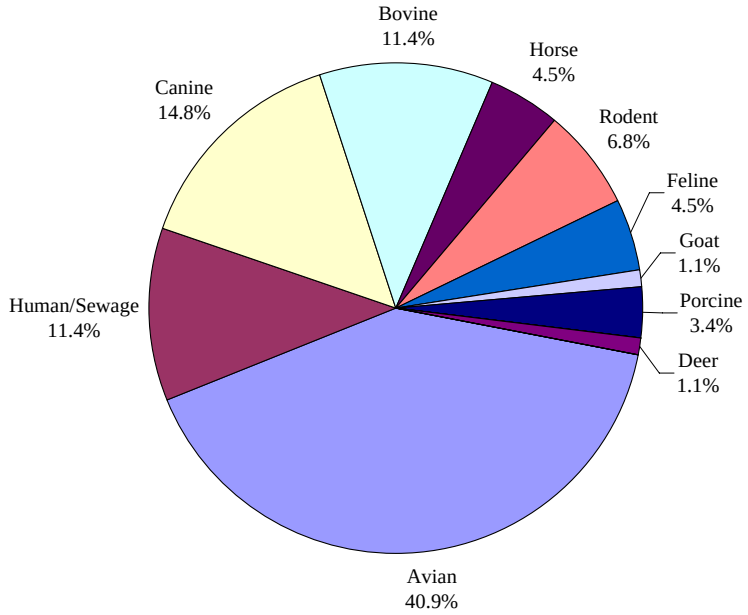
4.3.2.7 Rio Grande at Rio Bravo Bridge

Birds and livestock were the major sources identified at this site.

Table 4.13 Fecal Source Estimate for the Rio Grande at Rio Bravo Bridge

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	10	11.4 %	4.8 - 18.0 %
Bovine	10	11.4 %	4.8 - 18.0 %
Equine	4	4.5 %	0.1 - 9.9 %
Porcine	3	3.4 %	0 - 7.2 %
Goats	1	1.1 %	0 - 3.3 %
Livestock Subtotal	18	20.5 %	12.1 - 28.9 %
Avian Subtotal	36	40.9 %	30.6 - 51.2 %
Canines	13	14.8 %	7.4 - 22.2 %
Feline	4	4.5 %	0.1 - 9.9 %
Canine & Feline Subtotal	17	19.3 %	11.1 - 27.5 %
Rodent	6	6.8 %	1.5 - 12.1 %
Deer & elk	1	1.1 %	0 - 3.3 %
Non-Avian Wildlife Subtotal	7	8.0 %	2.3 - 13.7 %
Unknown	2		
Grand Total	90		

Figure 4.11 Sources of *E. coli* at Rio Grande at Rio Bravo Bridge



4.3.2.8 Rio Grande at the Interstate 25 Bridge

Birds and human/sewage were the major sources of fecal coliform identified at this site. Birds were a more significant source under non-runoff conditions than under runoff conditions.

Table 4.14 Fecal Source Estimate for the Rio Grande at the Interstate 25 Bridge

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	29	19.5 %	13.1 - 25.9 %
Bovine	14	9.4 %	4.7 - 14.1 %
Equine	7	4.7 %	1.3 - 8.1 %
Porcine	4	2.7 %	0.1 - 6.3 %
Sheep	1	0.7 %	0 - 2.0 %
Livestock Subtotal	26	17.4 %	11.3 - 23.5 %
Avian Subtotal	53	35.6 %	27.9 - 43.3 %
Canine	21	14.1 %	8.5 - 19.7 %
Feline	5	3.4 %	0.5 - 6.3 %
Canine & Feline Subtotal	26	17.4 %	11.3 - 23.5 %
Rodent	12	8.1 %	3.7 - 12.5 %
Deer & elk	2	1.3 %	0 - 3.1 %
Coyote	1	0.7 %	0 - 2.0 %
Non-Avian Wildlife Subtotal	15	10.1 %	5.3 - 14.9 %
Unknown	3		
Grand Total	152		

Figure 4.12 Sources of *E. coli* at Rio Grande at I-25

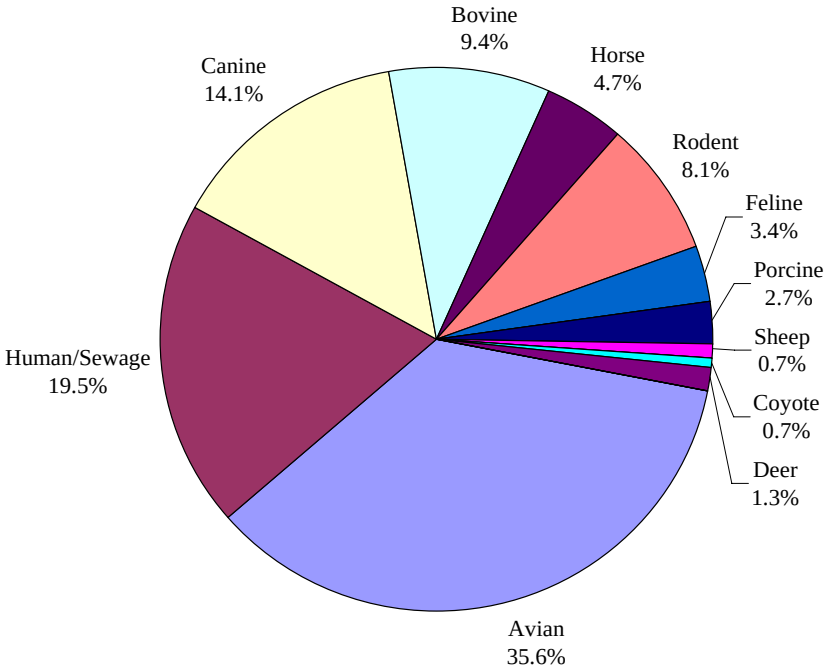


Table 4.15 Comparison of *E. coli* Sources in the Rio Grande at Interstate 25 under Runoff and Non-Runoff Conditions

Category	Runoff % Contribution	Runoff 95% Confidence Interval	Non-Runoff % Contribution	Non-Runoff 95% Confidence Interval
Human/Sewage Subtotal	22.7 %	13.3 – 32.0 %	16.2 %	7.9 – 24.6 %
Bovine	10.7 %	3.8 – 17.6 %	8.1 %	0 – 14.3 %
Equine	6.7 %	1.1 – 12.2 %	2.7 %	0 – 6.4 %
Porcine	4.0 %	0 – 8.4 %	1.4 %	0 – 4.0 %
Sheep	1.3 %	0 – 3.9 %	0 %	0 – <4.0 %
Livestock Subtotal	22.7 %	13.3 – 32.0 %	12.2 %	4.8 – 19.6 %
Avian Subtotal	25.3 %	15.6 – 35.0 %	45.9 %	34.7 – 57.2 %
Canine	17.3 %	8.9 – 25.8 %	**10.8 %**	3.8 – 17.8 %
Feline	2.7 %	0 – 6.3 %	4.1 %	0 – 8.5 %
Canine & Feline Subtotal	20.0 %	11.1 – 28.9 %	14.9 %	6.8 – 22.9 %
Rodent	6.7 %	1.1 – 12.2 %	9.5 %	2.8 – 16.1 %
Deer & Elk	1.3 %	0 – 3.9 %	1.4 %	0 – <4.0 %
Coyote	1.3 %	0 – 3.9 %	0 %	0 – <4.0 %
Non-Avian Wildlife Subtotal	9.3 %	2.8 – 15.8 %	10.8%	3.8 – 17.8 %
Unknown	2.6 %		1.3 %	

4.3.2.9 Rio Grande at Isleta Diversion Dam

Birds and livestock were the major fecal coliform sources identified in this watershed. *E. coli* from hogs and pigs were observed to a much greater extent in non-runoff, baseflow sampling, but overall they were a minor source.

Table 4.16 Fecal Source Estimate for the Rio Grande at Isleta Diversion Dam

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	21	11.2 %	6.7 - 15.7 %
Bovine	17	9.1 %	5.0 - 13.2 %
Equine	13	7.0 %	3.4 - 10.6 %
Porcine	6	3.2 %	0.7 - 5.9 %
Sheep	1	0.5 %	0 - 1.5 %
Livestock Subtotal	37	19.8 %	14.1 - 25.5 %
Avian Subtotal	81	43.3 %	36.2 - 50.4 %
Canines	24	12.8 %	8.0 - 17.6 %
Feline	1	0.5 %	0 - 1.5 %
Canine & Feline Subtotal	25	13.4 %	8.5 - 18.3 %
Rodent	20	10.7 %	6.3 - 15.1 %
Deer & elk	1	0.5 %	0 - 1.5 %
Raccoon	1	0.5 %	0 - 1.5 %
Bear	1	0.5 %	0 - 1.5 %
Non-Avian Wildlife Subtotal	23	12.3 %	7.6 - 17.0 %
Unknown	15		
Grand Total	202		

Figure 4.13 Sources of *E. coli* in the Rio Grande at Isleta Diversion Dam

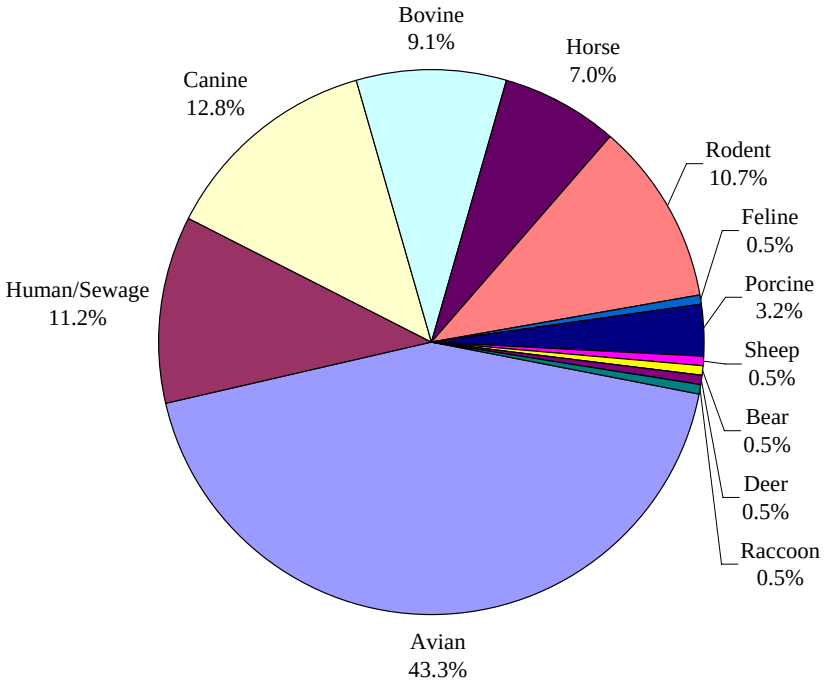


Table 4.17 Comparison of E. coli Sources in the Rio Grande at Isleta Diversion Dam under Runoff and Non-Runoff Conditions

Category	Runoff % Contribution	Runoff 95% Confidence Interval	Non-Runoff % Contribution	Non-Runoff 95% Confidence Interval
Human/Sewage Subtotal	12.4 %	6.6 – 18.1 %	14.6 %	3.8 – 25.5 %
Bovine	8.8 %	3.9 – 13.8 %	12.2 %	2.2 – 22.2 %
Equine	7.1 %	2.6 – 11.6 %	7.3 %	0 – 15.3 %
Porcine	0.9 %	0 – 2.5 %	12.2 %	2.2 – 22.2 %
Sheep	0.9 %	0 – 2.5 %	0 %	0 - <7.2 %
Livestock Subtotal	17.7 %	11.0 – 24.4 %	31.7 %	17.5 – 46.0 %
Avian Subtotal	41.6 %	33.0 – 50.2 %	41.5 %	26.4 – 56.5 %
Canine	13.3 %	7.3 – 19.2 %	7.3 %	0 – 15.3 %
Feline	0.9 %	0 – 2.5 %	0 %	0 - <7.2 %
Canine & Feline Subtotal	14.2 %	8.1 – 20.2 %	7.3 %	0 – 15.3 %
Rodent	11.5 %	5.9 – 17.1 %	4.9 %	0 – 11.5 %
Deer & Elk	0.9 %	0 – 2.5 %	0 %	0 - <7.2 %
Raccoon	0.9 %	0 – 2.5 %	0 %	0 - <7.2 %
Bear	0.9 %	0 – 2.5 %	0 %	0 - <7.2 %
Non-Avian Wildlife Subtotal	14.2 %	8.1 – 20.2 %	4.9 %	0 – 11.5 %
Unknown	10.3 %	5.0 – 15.6 %	0 %	0 - <7.2 %

4.3.2.10 North Diversion Channel at Roy

The major sources of fecal coliform at this site included birds, humans, canines, and rodents. Livestock sources comprised a greater portion of the *E. coli* tested under runoff conditions than base flow conditions, whereas birds were a more substantial source under base flow conditions, but the differences were not statistically significant at the 95 percent confidence level.

Table 4.18 Fecal Source Estimate for the North Diversion Channel at Roy

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	23	23.7 %	15.2 - 32.2 %
Equine	5	5.2 %	0.8 - 9.6 %
Porcine	3	3.1 %	0 - 6.5 %
Livestock Subtotal	8	8.2 %	2.7 - 13.7 %
Avian Subtotal	25	25.8 %	17.1 - 34.5 %
Canines	22	22.7 %	14.4 - 31.0 %
Canine & Feline Subtotal	22	22.7 %	14.4 - 31.0 %
Rodent	17	17.6 %	10.0 - 25.2 %
Deer & Elk	1	1.0 %	0 - 3.0 %
Coyote	1	1.0 %	0 - 3.0 %
Non-Avian Wildlife Subtotal	19	19.6 %	11.7 - 27.5 %
Unknown	9		
Grand Total	106		

Figure 4.14 Sources of *E. coli* in the North Diversion Channel at Roy

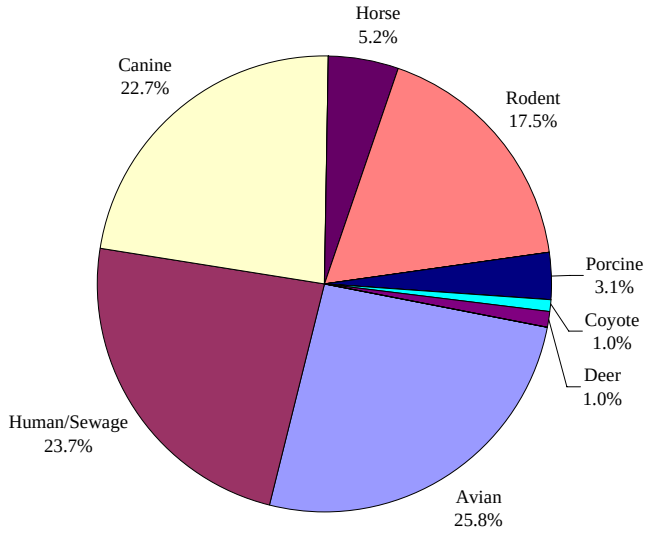


Table 4.19 Comparison of *E. coli* Sources at the North Diversion Channel under Runoff and Non-Runoff Conditions

Category	Runoff % Contribution	Runoff 95% Confidence Interval	Non-Runoff % Contribution	Non-Runoff 95% Confidence Interval
Human/Sewage Subtotal	20.8 %	9.9 – 31.8 %	26.5 %	14.6 – 38.4 %
Equine	8.3 %	0.9 – 15.8 %	2.0 %	0 – 5.8 %
Porcine	6.3 %	0 – 12.8 %	0	0 – <5.8 %
Livestock Subtotal	14.6 %	5.1 - 24.1 %	2.0 %	0 – 5.8 %
Avian Subtotal	18.8 %	8.2 – 29.3 %	32.7 %	20.0 – 45.3 %
Canine	20.8 %	9.9 – 31.8 %	24.5 %	12.9 – 36.1 %
Canine & Feline Subtotal	20.8 %	9.9 – 31.8 %	24.5 %	12.9 – 36.1 %
Rodent	20.8 %	9.9 – 31.8 %	14.3 %	4.9 – 23.7 %
Deer & Elk	1.9 %	0 – 5.9 %	0	0 – <5.8 %
Coyote	1.9 %	0 – 5.9 %	0	0 – <5.8 %
Non-Avian Wildlife Subtotal	25.0 %	13.3 - 36.7 %	14.3 %	4.9 – 23.7 %
Unknown	9.4 %		7.5 %	

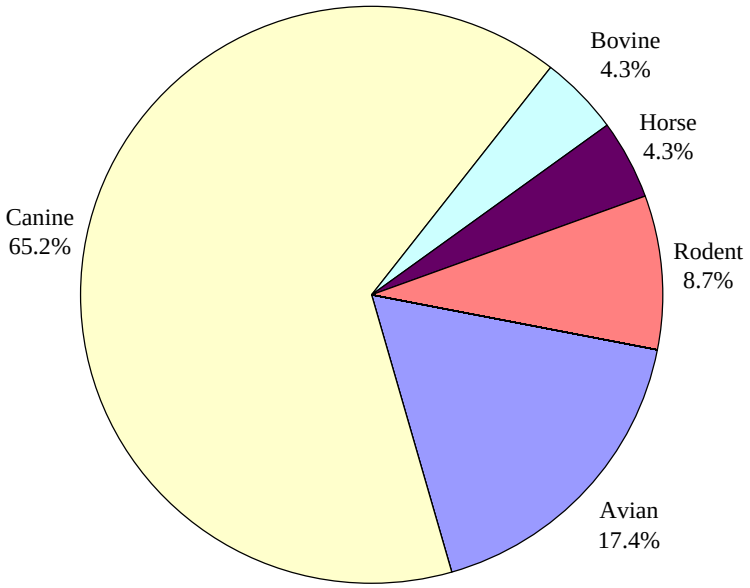
4.3.2.11 North Domingo Baca Arroyo Dam at Primary Spillway

Canines were the major source of fecal coliform isolated from this site.

Table 4.20 Fecal Source Estimate for North Domingo Baca Arroyo Dam at Primary Spillway

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	0	0 %	
Bovine	1	4.3 %	0 - 12.6 %
Equine	1	4.3 %	0 - 12.6 %
Livestock Subtotal	2	8.7 %	0 - 20.2 %
Avian Subtotal	4	17.4 %	1.9 - 32.9 %
Canine	15	65.2 %	45.7 - 84.7 %
Canine & Feline Subtotal	15	65.2 %	45.7 - 84.7 %
Rodent	2	8.7 %	0 - 20.2 %
Non-Avian Wildlife Subtotal	2	8.7 %	0 - 20.2 %
Unknown	2		
Grand Total	25		

Figure 4.15 Sources of *E. coli* in North Domingo Baca Arroyo Dam at Primary Spillway



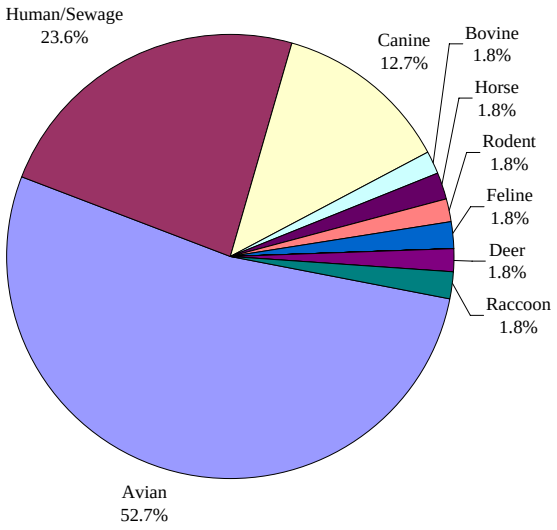
4.3.2.12 North Pino Arroyo above North Diversion Channel

Birds and humans/sewage were the major sources of fecal coliform at this site.

Table 4.21 Fecal Source Estimate for North Pino Arroyo above North Diversion Channel

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	13	23.6 %	12.4 - 34.8 %
Bovine	1	1.8 %	0 - 5.3 %
Horses	1	1.8 %	0 - 5.3 %
Livestock Subtotal	2	3.6 %	0 - 8.1 %
Avian Subtotal	29	52.7 %	39.5 - 65.9 %
Canines	7	12.7 %	3.9 - 21.5 %
Feline	1	1.8 %	0 - 5.3 %
Canine & Feline Subtotal	8	14.5 %	5.2 - 23.8 %
Rodent	1	1.8 %	0 - 5.3 %
Deer & elk	1	1.8 %	0 - 5.3 %
Raccoon	1	1.8 %	0 - 5.3 %
Non-Avian Wildlife Subtotal	3	5.4 %	0 - 11.4 %
Unknown	3		
Grand Total	58		

Figure 4.16 Sources of E. coli to North Pino Arroyo above North Diversion Channel



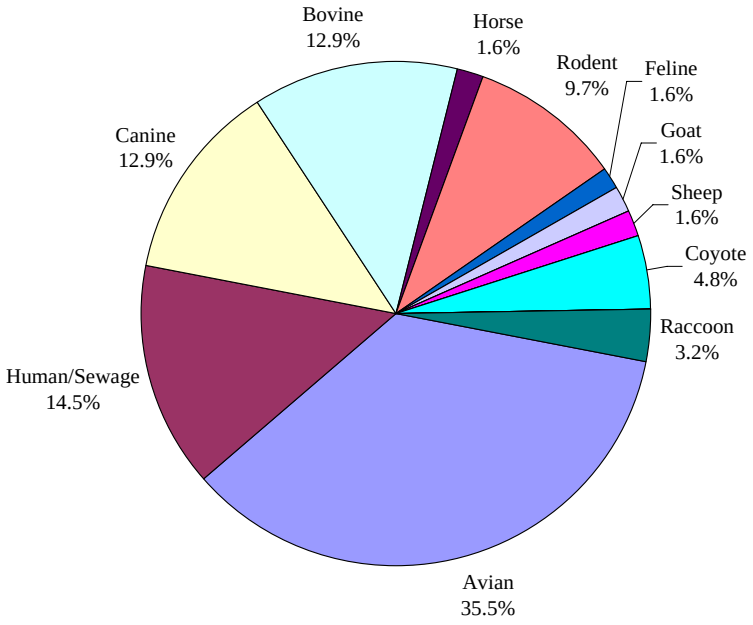
4.3.2.13 Hahn Arroyo above North Diversion Channel

Birds were the major source of fecal coliform at this site. The presence of bovine sources was somewhat surprising in this urban watershed. It may be due to manure spread in gardens. Four of the eight samples matched to bovine feces originated in a single water sample. The sources of 11 *E. coli* were unknown.

Table 4.22 Fecal Source Estimate for Hahn Arroyo above North Diversion Channel

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	9	14.5 %	5.7 - 23.3 %
Equine	8	12.9 %	4.6 - 21.2 %
Horses	1	1.6 %	0 - 4.7 %
Sheep	1	1.6 %	0 - 4.7 %
Goats	1	1.6 %	0 - 4.7 %
Livestock Subtotal	11	17.7 %	8.2 - 26.2 %
Avian Subtotal	22	35.5 %	23.6 - 47.4 %
Canines	8	12.9 %	4.6 - 21.2 %
Feline	1	1.6 %	0 - 4.7 %
Canine & Feline Subtotal	9	14.5 %	5.7 - 23.3 %
Rodent	6	9.7 %	2.3 - 17.1 %
Coyote	3	4.8 %	0 - 10.1 %
Raccoon	2	3.2 %	0 - 7.6 %
Non-Avian Wildlife Subtotal	11	17.7 %	8.2 - 26.2 %
Unknown	11		
Grand Total	73		

Figure 4.17 Sources of *E. coli* to Hahn Arroyo above North Diversion Channel



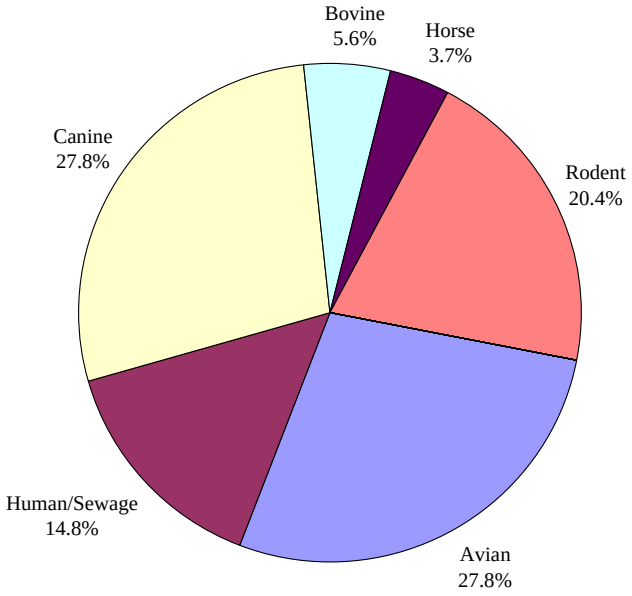
4.3.2.14 Embudo Channel above Confluence with North Diversion Channel

Birds, canines, and rodents were the major sources of fecal coliform at this site.

Table 4.23 Fecal Source Estimate for the Embudo Channel above the North Diversion Channel

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	8	14.8 %	5.3 - 24.3 %
Bovine	3	5.6 %	0 - 11.7 %
Equine	2	3.7 %	0 - 8.7 %
Livestock Subtotal	5	9.3 %	1.6 - 17.0 %
Avian Subtotal	15	27.8 %	15.9 - 39.7 %
Canines	15	27.8 %	15.9 - 39.7 %
Canine & Feline Subtotal	15	27.8 %	15.9 - 39.7 %
Rodent	11	20.4 %	9.7 - 31.1 %
Non-Avian Wildlife Subtotal	11	20.4 %	9.7 - 31.1 %
Unknown	21		
Grand Total	75		

Figure 4.18 Sources of *E. coli* to the Embudo Channel above the North Diversion Channel



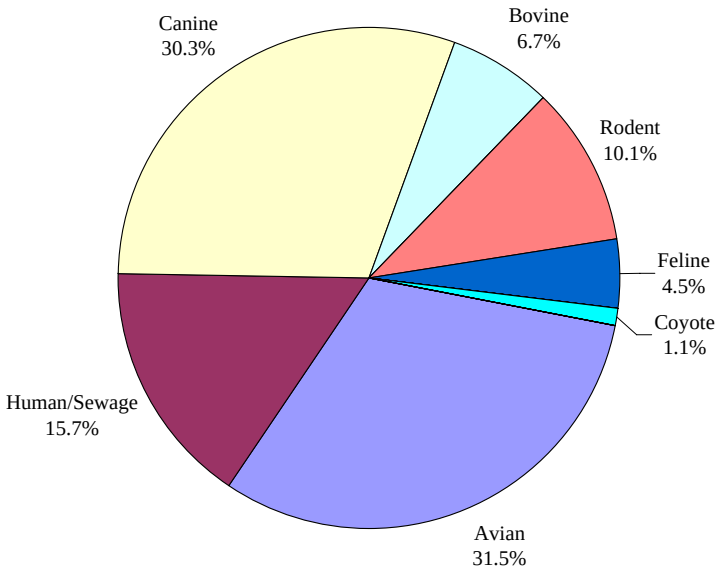
4.3.2.15 South Diversion Channel above Tijeras Arroyo

Birds and canines were the major sources at this site.

Table 4.24 Fecal Source Estimate for the South Diversion Channel above Tijeras Arroyo

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	14	15.7 %	8.1 - 23.3 %
Bovine	6	6.7 %	1.5 - 11.9 %
Livestock Subtotal	6	6.7 %	1.5 - 11.9 %
Avian Subtotal	28	31.5 %	21.9 - 41.1 %
Canines	27	30.3 %	20.7 - 39.9 %
Feline	4	4.5 %	0.2 - 8.8 %
Canine & Feline Subtotal	31	34.8 %	24.9 - 44.7 %
Rodent	9	10.1 %	3.8 - 16.4 %
Coyote	1	1.1 %	0 - 3.3 %
Non-Avian Wildlife Subtotal	10	11.2 %	4.6 - 17.8 %
Unknown	2		
Grand Total	91		

Figure 4.19 Sources of *E. coli* to the South Diversion Channel above Tijeras Arroyo



4.3.2.16 Sandia Natural Arroyo at I-25

Only four *E. coli* collected at this site were ribotyped. Therefore, the source contributions cannot be estimated.

4.3.2.17 Paseo del Norte Pump Station

Only two isolates were ribotyped from this site; both matched canine sources. The source contributions cannot be estimated due to the small number of isolates typed.

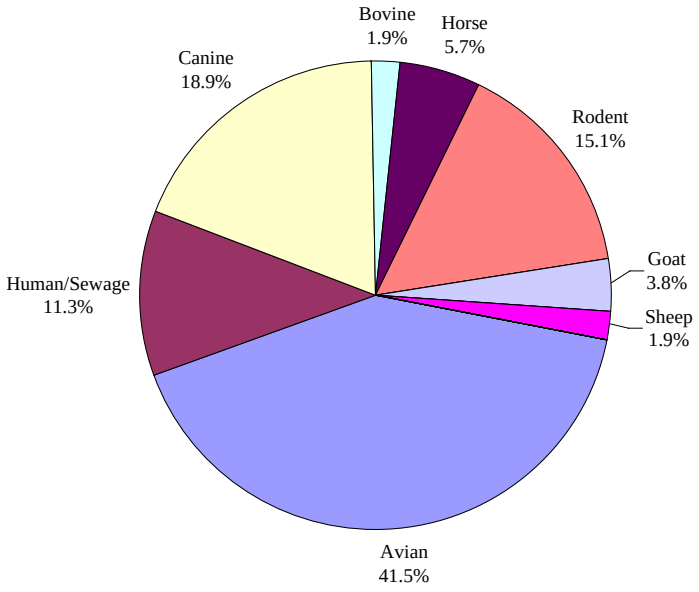
4.3.2.18 Alameda Drain at Ranchitos Road

Birds were the major source of fecal coliform at this site.

Table 4.25 Fecal Source Estimate for Alameda Drain at Ranchitos Road

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	6	11.3 %	2.8 - 19.8 %
Bovine	1	1.9 %	0 - 5.6 %
Equine	3	5.7 %	0 - 11.9 %
Sheep	1	1.9 %	0 - 5.6 %
Goats	2	3.8 %	0 - 8.9 %
Livestock Subtotal	7	13.2 %	4.1 - 22.3 %
Avian Subtotal	22	41.5 %	28.2 - 54.8 %
Canines	10	18.9 %	8.4 - 29.4 %
Canine & Feline Subtotal	10	18.9 %	8.4 - 29.4 %
Rodent	8	15.1 %	5.5 - 24.7 %
Non-Avian Wildlife Subtotal	8	15.1 %	5.5 - 24.7 %
Unknown	3		
Grand Total	56		

Figure 4.20 Sources of *E. coli* to the Alameda Drain at Ranchitos Road



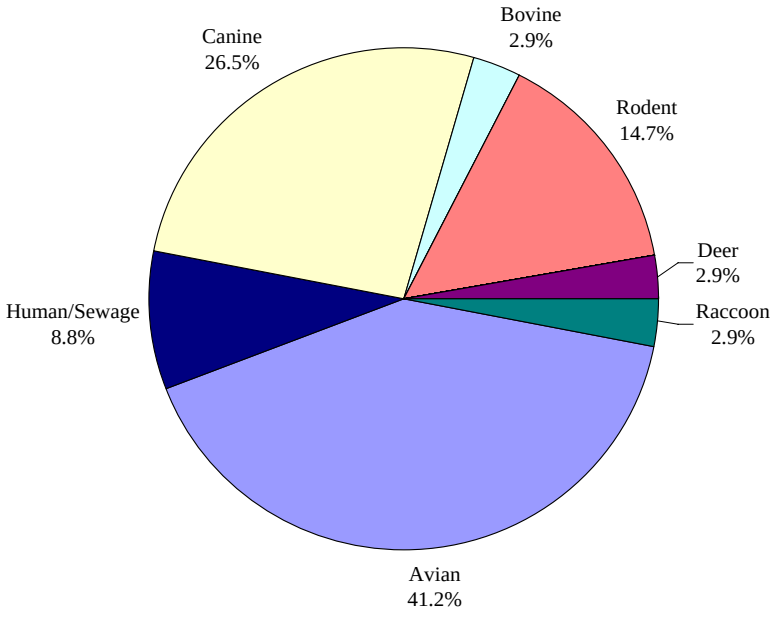
4.3.2.19 Alameda Drain at El Caminito Crossing

Birds, canines, and rodents were the major sources of fecal coliform identified in samples from this site. Although septic tanks were abundant in this watershed, sewage was not found to be a major source.

Table 4.26 Fecal Source Estimate for Alameda Drain at El Caminito Crossing

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	3	8.8 %	0 - 18.3 %
Bovine	1	2.9 %	0 - 8.6 %
Livestock Subtotal	1	2.9 %	0 - 8.6 %
Avian Subtotal	14	41.2 %	24.7 - 57.7 %
Canines	9	26.5 %	11.7 - 41.3 %
Canine & Feline Subtotal	9	26.5 %	11.7 - 41.3 %
Rodent	5	14.7 %	2.8 - 26.6 %
Deer & elk	1	2.9 %	0 - 8.6 %
Raccoon	1	2.9 %	0 - 8.6 %
Non-Avian Wildlife Subtotal	7	20.6 %	7.0 - 34.2 %
Unknown	2		
Grand Total	36		

Figure 4.21 Sources of *E. coli* to the Alameda Drain at El Caminito Crossing



4.3.2.20 Ranchitos de Albuquerque Storm Drain

Because only seven isolates were typed from this site, a reliable estimation of fecal sources cannot be made. Three of the seven isolates matched *E. coli* from rodent hosts, two matched canines, and one each matched bovine and avian-resident strains of *E. coli*.

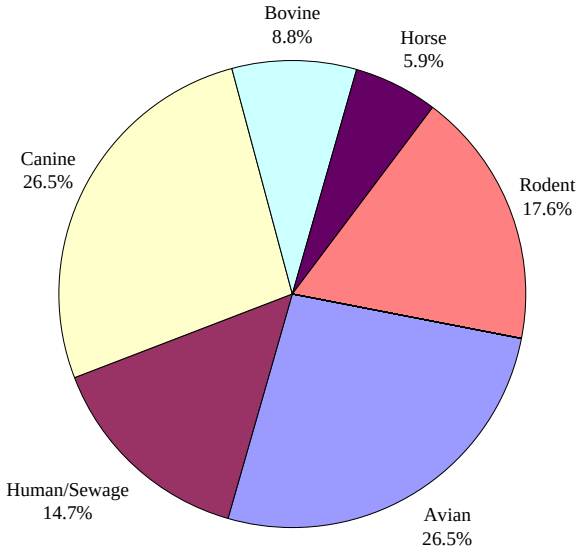
4.3.2.21 Cabezon Channel

Birds and canines were the major sources of fecal coliform identified at this site.

Table 4.27 Fecal Source Estimate for the Cabezon Channel

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	5	14.7 %	2.8 - 26.6 %
Bovine	3	8.8 %	0 - 18.7 %
Equine	2	5.9 %	0 - 13.8 %
Livestock Subtotal	5	14.7 %	2.8 - 26.6 %
Avian Subtotal	9	26.5 %	11.7 - 41.3 %
Canines	9	26.5 %	11.7 - 41.3 %
Canine & Feline Subtotal	9	26.5 %	11.7 - 41.3 %
Rodent	6	17.6 %	4.8 - 30.4 %
Non-Avian Wildlife Subtotal	6	17.6 %	4.8 - 30.4 %
Unknown	0		
Grand Total	34		

Figure 4.22 Sources of *E. coli* to the Cabezon Channel



4.3.2.22 Calabacillas Arroyo at Swinburne Dam

While five of the 19 isolates from this site did not match any isolates from known sources, the other 14 isolates all matched canine-resident isolates. However, all of the isolates were from a single composite water sample, which may explain the lack of diversity. For this reason, a reliable source estimation cannot be made for this site.

4.3.2.23 Calabacillas Arroyo at Coors Road

The identified sources at this site were evenly distributed among human sewage, avian, rodent, and other sources. Eight of the 23 isolates from this site did not match any *E. coli* from known sources. With only 15 *E. coli* matching known sources, a reliable source estimation cannot be performed. Of the 15 *E. coli* matching those from known sources, there were four matching sewage-specific ribotypes, four matching avian-specific ribotypes, four matching rodent-specific ribotypes, and one each matching bovine-, canine-, and feline-specific ribotypes.

4.3.2.24 Amole del Norte Channel Above Amole Dam

Given the small human population of this watershed, the large number of human sewage resident *E. coli* strains is unexpected. However, the total number of isolates was low, and all 24 isolates were from the same composite water sample. For this reason, a reliable source estimation cannot be made for this site.

Table 4.28 Fecal Source Estimate for the Amole del Norte Channel above Amole Dam

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	10	47.6 %	26.2 – 69.0 %
Bovine	1	4.8 %	0 – 13.9 %
Equine	2	9.5 %	0 – 22.1 %
Livestock Subtotal	3	14.3 %	0 – 29.3 %
Avian Subtotal	7	33.3 %	13.1 – 53.4 %
Canines	1	4.8 %	0 – 13.9 %
Canine & Feline Subtotal	1	4.8 %	0 – 13.9 %
Non-Avian Wildlife Subtotal	0	0 %	
Unknown	3		
Grand Total	24		

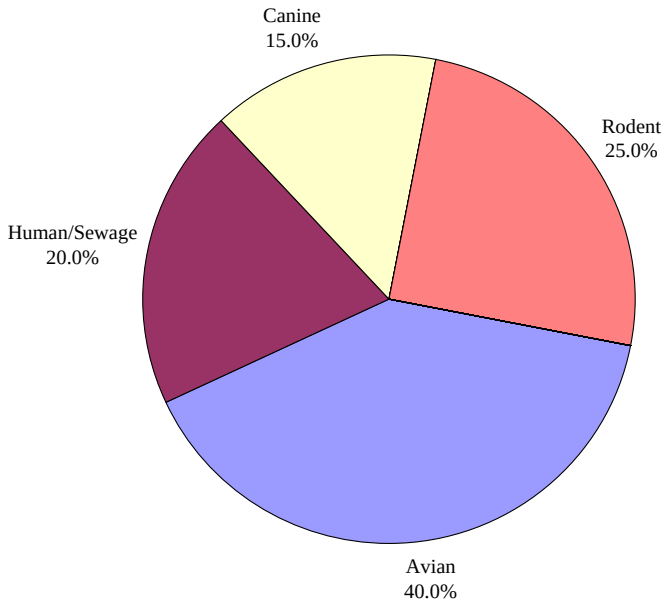
4.3.2.25 Vito Romero Pump Station

Birds and rodents were the major sources identified in this small, densely populated watershed. No livestock sources were noted. However, because the number of isolates typed was low, the uncertainty of the source estimates was high.

Table 4.29 Fecal Source Estimate for Vito Romero Pump Station

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	4	20 %	2.5 – 37.5 %
Livestock Subtotal	0	0 %	
Avian Subtotal	8	40 %	18.5 – 61.5 %
Canine	3	15 %	0 – 30.6 %
Canine & Feline Subtotal	3	15 %	0 – 30.6 %
Rodent	5	25 %	6 – 44 %
Non-Avian Wildlife Subtotal	5	25 %	6 – 44 %
Unknown	0		
Grand Total	20		

Figure 4.23 Sources of *E. coli* to Vito Romero Pump Station



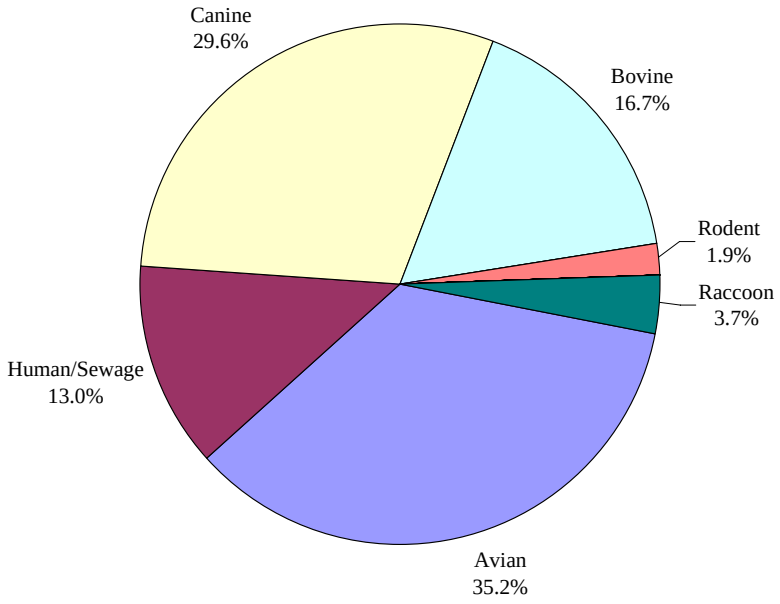
4.3.2.26 Los Padillas Drain Immediately Upstream of the Isleta Drain

Birds and canines were the major sources of fecal coliform identified at this site. A large number of isolates did not match strains from the known source library.

Table 4.30 Fecal Source Estimate for the Los Padillas Drain Immediately Upstream of the Isleta Drain

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	7	13.0 %	4.0 – 22.0 %
Bovine	9	16.7 %	6.8 – 26.6 %
Livestock Subtotal	9	16.7 %	6.8 – 26.6 %
Avian Subtotal	19	35.2 %	22.5 – 47.9 %
Canine	16	29.6 %	17.4 – 41.8 %
Canine & Feline Subtotal	16	29.6 %	17.4 – 41.8 %
Rodent	1	1.9 %	0 – 5.5 %
Raccoon	2	3.7 %	0 – 8.7 %
Non-Avian Wildlife Subtotal	3	5.6 %	0 – 11.7 %
Unknown	25		
Grand Total	79		

Figure 4.24 Sources of *E. coli* to the Los Padillas Drain Immediately Upstream of the Isleta Drain



4.3.2.27 Isleta Drain Immediately Upstream of the Los Padillas Drain

Birds were the major source of fecal coliform in water at this site.

Table 4.31 Fecal Source Estimate for the Isleta Drain Immediately Upstream of the Los Padillas Drain

Category	Number of Isolates	% Source Contribution	95% Confidence Limits
Human/ Sewage Subtotal	6	13.0 %	3.3 – 22.7 %
Bovine	2	4.3 %	0 – 10.2 %
Equine	2	4.3 %	0 – 10.2 %
Porcine	2	4.3 %	0 – 10.2 %
Sheep	2	4.3 %	0 – 10.2 %
Livestock Subtotal	8	17.4 %	6.4 – 28.4 %
Avian Subtotal	19	41.3 %	27.1 – 55.5 %
Canine	6	13.0 %	3.3 – 22.7 %
Canine & Feline Subtotal	6	13.0 %	3.3 – 22.7 %
Rodent	7	15.2 %	4.8 – 25.6 %
Non-Avian Wildlife Subtotal	7	15.2 %	4.8 – 25.6 %
Unknown	0		
Grand Total	46		

Figure 4.25 Sources of *E. coli* to the Isleta Drain Immediately Upstream of the Los Padillas Drain

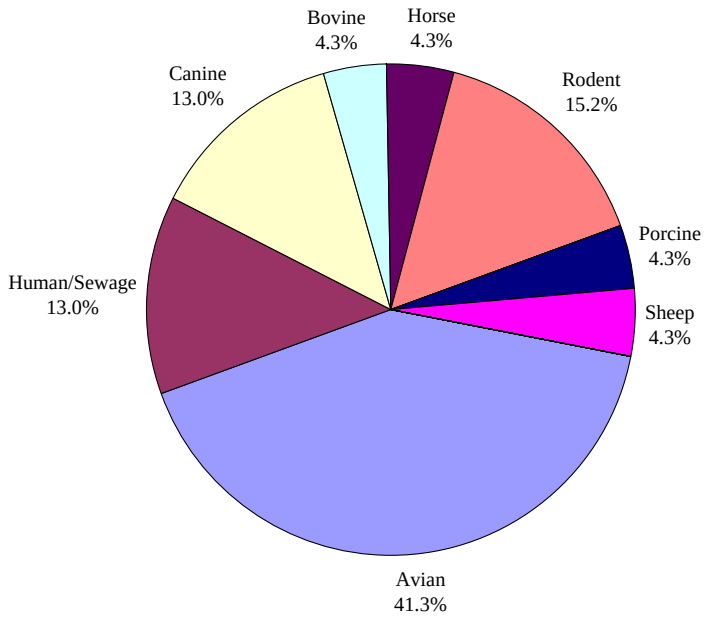


Table 4.32 Ribotype-Based Source Identification Summarized at the Supercategory Level by Site

Site Number	Station Description	Human/ Sewage	Avian	Livestock	Canine & Feline	Non-Avian Wildlife	Unknown	Total
1	Rio Grande at Angostura Diversion Dam	3	7	10	15	5	1	41
2	Rio Grande at Highway US 550	9	17	8	20	10	3	67
3	Rio Grande above Rio Rancho Utility #3	13	25	6	23	12	3	82
4	Rio Grande above Rio Rancho Utility #2	19	17	8	24	7	14	89
5	Rio Grande at Alameda Bridge	19	32	21	31	12	4	119
6	Rio Grande at Rio Bravo Bridge	10	36	18	17	7	2	90
7	Rio Grande at Interstate 25 Bridge	29	53	26	26	15	3	152
8	Rio Grande at Isleta Diversion Dam	21	81	37	25	23	15	202
9	North Diversion Channel at Roy	23	25	8	22	19	9	106
10	North Domingo Baca Arroyo Dam at Primary Spillway	0	4	2	15	2	2	25
11	North Pino Arroyo above North Diversion Channel	13	29	2	8	3	3	58
12	Hahn Arroyo above North Diversion Channel at Carlisle	9	22	11	9	11	11	73
13	Embudo Channel above confluence with North Diversion Channel	8	15	5	15	11	21	75
15	South Diversion Channel above Tijeras Arroyo	14	28	6	31	10	2	91
16	Sandia Pueblo Natural Arroyo at I-25	0	2	0	2	0	0	4
17	Paseo del Norte Pump Station	0	0	0	2	0	0	2
18	Alameda Drain at Ranchitos Road	6	22	7	10	8	3	56
19	Alameda Drain at El Caminito Crossing	3	14	1	9	7	2	36
20	Ranchitos de Albuquerque Storm Drain	0	1	1	2	3	0	7

Site Number	Station Description	Human/ Sewage	Avian	Livestock	Canine & Feline	Non-Avian Wildlife	Unknown	Total
21	Cabezon Channel	5	9	5	9	6	0	34
22	Calabacillas Arroyo at Swinburne Dam	0	0	0	14	0	5	19
23	Calabacillas Arroyo at Coors Road	4	4	1	2	4	8	23
26	Amole del Norte Channel above Amole Dam	10	7	3	1	0	3	24
28	Vita Romero Pump Station	4	8	0	3	5	0	20
29	Los Padillas Drain just upstream of the confluence with the Isleta Drain	7	19	9	16	3	25	79
30	Isleta Drain just upstream of the confluence with Los Padillas Drain	6	19	8	6	7	0	46
	Grand Total	235	496	203	357	190	139	1620

4.4 Antibiotic Resistance Analysis Results

The 2,214 *E. coli* isolates subjected to ARA included 462 isolates from known sources and 1,752 from ambient water samples. Ninety nine different ARPs were observed among the *E. coli*. The most common ARP, with 1,711 isolates, was *E. coli* susceptible to all 12 of the antibiotics. There was no antibiotic to which all *E. coli* were susceptible. The number of *E. coli* resistant to each antibiotic is listed in Table 4.33, and complete data are provided in Appendix B.

The utility of ARA in identifying fecal sources was limited in this study. First, as noted above, 77 percent of the samples were susceptible to all 12 antibiotics. Second, there was a variety of sources associated with most of the antibiotic resistance profiles, and the number of known source isolates associated with each ARP was insufficient to reliably indicate a significant source association. There were a few exceptions: ARPs with resistance to ciprofloxacin or nalidixic acid were more commonly observed from known sewage or human samples, but these were seldom found in water samples. For these reasons, an attempt to identify fecal sources based on ARA was not made.

Table 4.33 *E. coli* Antibiotic Resistance

Antibiotic	Resistant *E. coli* Count (of 2214 total isolates)	Known Source Associations
Amikacin	15	
Ampicillin	228	sewage/human, feline, avian, bovine
Ampicillin/sulbactam	32	sheep
Ceftriaxone	3	
Chloramphenicol	2	
Ciprofloxacin	130	human/sewage, avian
Gentamicin	27	
Kanamycin	35	canine, porcine
Nalidixic acid	84	sewage
Streptomycin	228	sewage, avian, sheep, porcine, canine, feline
Tetracycline	163	sewage, poultry, sheep, avian
Trimethoprim	89	sewage, horse, avian

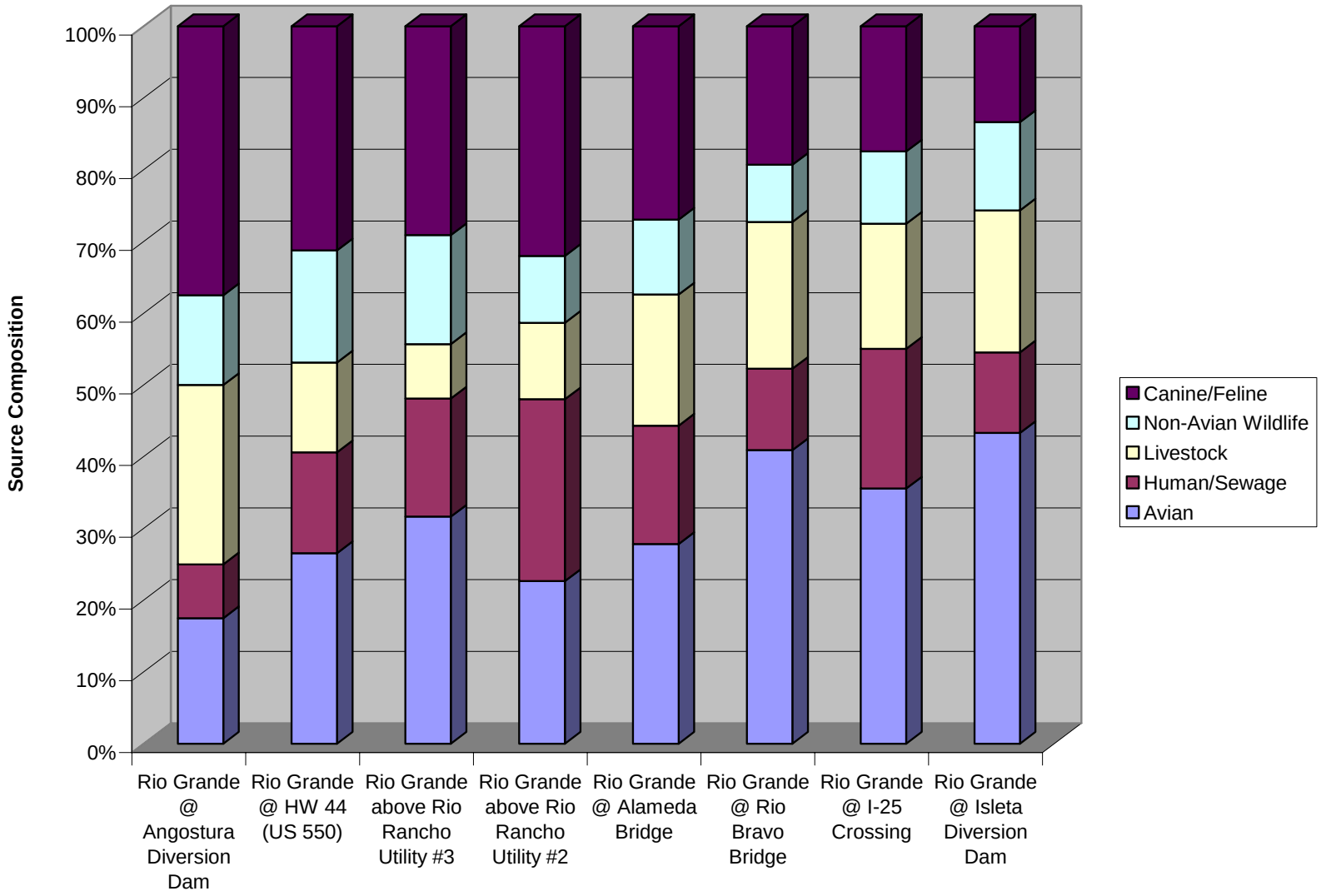
4.5 Geographic Relationships with Identified Sources

There appears to be an increase in the relative abundance of avian sources from upstream to downstream along the MRG, while the relative abundance of canine sources declines (Figure 4.26). The urbanization of the MRG watershed also increases from upstream to downstream. Urban areas provide an abundance of suitable habitat and food supply for many species of birds which concentrate in urban areas. The reduction in the relative importance of canine and feline sources of fecal coliform with the increasingly developed nature of the watershed runs counter to expectations. Parsons assumed that the sheer number of dogs in urban areas would cause an increase in fecal loading to water, in both absolute and relative terms, with increasing urbanization of the watershed. This was

not observed. In addition, several of the relatively undeveloped small watersheds indicated a major canine source. It may be that a large population of canines in less developed portions of the watershed, and/or efficient dog waste cleanup in urban areas, may be responsible for the observations. In either case, canines represent a major source of fecal coliform in the watershed.

The relative importance of livestock as a source of fecal coliform in the MRG was highest at the uppermost site at Angostura, declines, and then increases again in the lower river reaches. The relative importance of human/sewage as a fecal source in the river appears to be highest at sites in the vicinity of the permitted WWTF outfalls of Rio Rancho Utilities #2 and #3 and the City of Albuquerque. This may indicate that the NPDES-treated sewage discharges outweigh leaking sewers and malfunctioning septic tanks as fecal sources.

Figure 4.26 Changes in Fecal Source Composition in the Rio Grande with Distance Downstream



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