Section 4
Water Quality

4.1 Introduction

A water-quality assessment was conducted to evaluate the stream chemistry in the watershed with the goal of developing a watershed-management strategy that meets the requirements of the City's NPDES permit. The assessment utilized data obtained through: (1) a compilation of historic water-quality data in the watershed; and (2) limited water quality sampling at two locations in the watershed.

4.2 Methodology

Past stream-chemistry data were compiled from several sources, including the U.S. Geological Survey (USGS) National Water Information System (http://nwis.waterdata.usgs.gov/nwis), the Environmental Protection Agency STORET database (http://www.waterqualitydata.us/), the Nebraska Department of Environmental Quality (Dave Ihrie, written communication, 2014), and Kister and Mundorff (1963).

In addition, samples were collected for this study at six locations. Most locations included two dry-weather samples and one wet-weather sample. Though stream chemistry can be characterized a majority of the time by dry-weather sampling, a large portion of chemical loading occurs during runoff events, and thus an effort was made for at least one wet-weather sample for most locations.

The six sample locations were (Figure 4-1):

- Hickman Branch Tributary at Wittstruck Rd near Hickman, Nebr. (USGS station number 404008096354701);
- Salt Creek at Roca, Nebr. (USGS station number 06803000);
- Salt Creek Tributary near S 14th St and Rokeby Rd at Lincoln, Nebr. (USGS station number 404302096421301);
- Salt Creek Tributary near S 14th St and Vavrina Blvd at Lincoln, Nebr. (USGS station number 404400096420501);
- Salt Creek at Pioneers Blvd at Lincoln, Nebr. (USGS station number 06803080); and
- Salt Creek at W O St. at Lincoln, Nebr. (USGS station number 06803185).

Though wet-weather samples were anticipated on May 1, 2013, samples for all but one site—the Salt Creek Tributary near S 14th St and Vavrina Blvd—were classified as dry weather because significant rainfall did not commence until late in the day. Another set of dry weather samples were collected on August 7, 2013 with the exception of the tributary near S 14th St and Rokeby Rd, which was dry. Wet-weather samples were collected on either November 5, 2013 or November 6, 2013, depending on the location. A final dry-weather sample from the Vavrina Blvd site was collected on November 14, 2013.

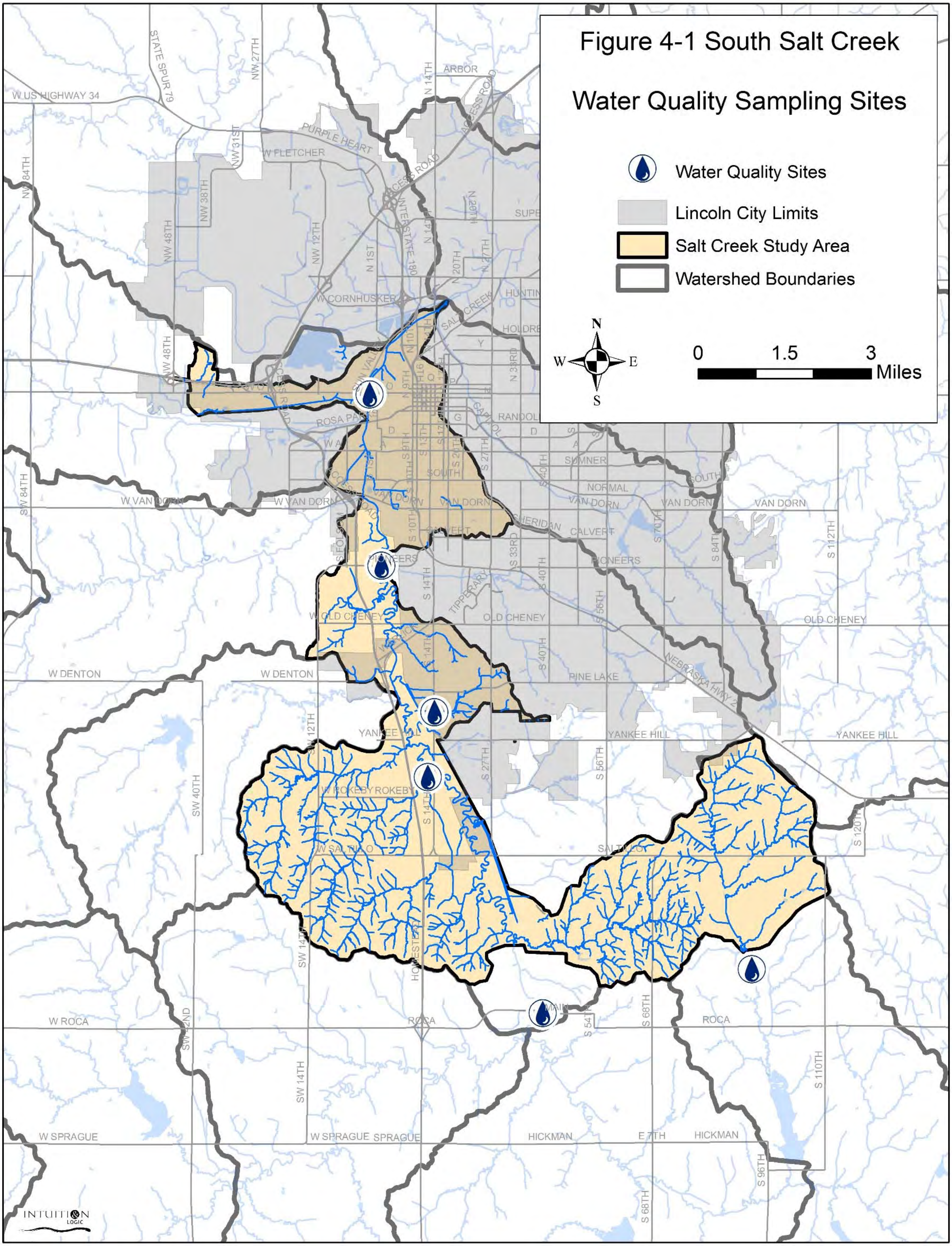
Figure 4-1 South Salt Creek
Water Quality Sampling Sites
Water Quality Sites
Lincoln City Limits
Salt Creek Study Area
Watershed Boundaries
N
S
E
W
0
1.5
3
Miles
W US HIGHWAY 34
W VAN DORN
W DENTON
W ROCA
W SPRAGUE
OLD CHENEY
YANKEE HILL
PINE LAKE
SALTILLO
ROCA
HICKMAN
INTUITION LOGIC

4.2.1 Sampling Protocol

Samples were collected by the USGS using the protocols described in the USGS National Field Manual (US Geological Survey, variously dated). All samples were collected by wading to the approximate centroid of flow where grab-sampling techniques were used to triple rinse and then fill a series of polyethylene bottles. Sample bottles requiring acid preservation were acidified in the field. For dissolved constituents, some of the sample bottles were filtered from one bottle into a separate, triple-rinsed bottle using a polysulfone, pleated-membrane capsule filter having a pore size of 0.45 μm. All samples were stored on ice or refrigerated until their delivery to analytical laboratories.

For quality-assurance purposes, two replicates and one blank sample were also collected. No analytes were detected in the blank sample. With the exception of *E. coli*, all of the analytes had good reproducibility in the replicate samples. The two *E. coli* results had an average relative-standard deviation of 27 percent. All *E. coli* results were analyzed using the regulatory standard known as the Quanti-Tray method (standard method 9223B) that, based on nationwide proficiency testing, is often characterized by variability of up to 40 percent.

In addition to the water samples, several ancillary data were collected. Water temperature, specific conductance, pH, dissolved oxygen, and turbidity were all measured using a multi-parameter meter calibrated on the day of collection. Velocity was estimated at the water surface using floating objects and then the mean velocity was assumed to be approximately 85% of that at the surface. Streamflows at the Salt Creek sites at Roca and Pioneers Blvd were taken from the USGS gaging-station data there. Streamflows at the other sites were either estimated as the product of the mean velocity and the cross-sectional area of the stream or, when possible, measured directly using a Parshall Flume.

4.2.2 Analytical Procedures

Analytes were selected in conjunction with the needs of the City and the respective NPDES permit. With the exception of the bacteriological results, all of the analytical chemistry was performed at the USGS National Water Quality Laboratory (NWQL):

Table 4.1 Analytes evaluated for each sample

Analyte	Laboratory	Units	Reporting Level	Reference
Dissolved calcium	NWQL	mg/L	0.022	Fishman, 1993
Dissolved magnesium	NWQL	mg/L	0.011	
Dissolved sodium	NWQL	mg/L	0.06	
Dissolved ammonia as nitrogen	NWQL	mg/L	0.010	
Dissolved copper	NWQL	μg/L	0.8	Garbarino and others, 2006
Dissolved selenium	NWQL	μg/L	0.05	
Hardness, as calcium carbonate	Calculated	mg/L	--	Fishman and Friedman, 1989
Sodium adsorption ratio	Calculated	unitless	--	
Total suspended solids	NWQL	mg/L	15	
Total phosphorus	NWQL	mg/L	0.020	Patton and Truitt, 1992
Total organic carbon	NWQL	mg/L	0.7	Standard Method 5310B
E. coli	NEHDL	MPN/100 mL	1	Standard Method 9223B
Total coliform	NEHDL	MPN/100 mL	1	

4.3 Results

Data from past sampling efforts and the sampling done as part of this study are compiled as geometric means in Table 4.2 and presented in their entirety in Appendix D. The three sample sets collected for this study range across the spring, summer, and fall seasons and most include a wet-weather sample from November 2013. The addition of past sampling added 455 samples in the Salt Creek Tributaries apart from that collected as part of this study. This added data for seven sites beyond those sampled for this study:

- Wagon Train Lake Unnamed Tributary North Inflow;
- Salt Creek at Saltillo Rd near Lincoln, Nebr.;
- Salt Creek at Park Blvd at Lincoln, Nebr.;
- Salt Creek at W South St. at Lincoln, Nebr.;
- Salt Creek at A St. at Lincoln, Nebr.;
- Salt Creek at Charleston St. at Lincoln, Nebr.; and
- Salt Creek at S 14th St at Lincoln, Nebr.

It also added new types of data, and atrazine concentrations were included in the summaries. However, these data represent only snapshots of the true water-quality conditions. Achieving a more balanced and accurate understanding of the water quality requires repeated sampling during the full range of flow conditions, agricultural activity and seasons. All of the data associated with the USGS are also available online through the National Water Information System (http://nwis.waterdata.usgs.gov/nwis).

4.3.1 Applicability to Water-Quality Criteria

The Salt South Watershed is comprised of Salt Creek and many of the smaller tributaries that contribute to it. Throughout the study reach, Salt Creek is designated for recreational use, warmwater aquatic life (class A), and aesthetics (NDEQ title 117). Site-specific water quality criteria exist for ammonia, and the key species are channel catfish and walleye. The southern portions of Salt Creek, from the confluence of Beal Slough to the confluence of Salt Creek's Hickman Branch, are also designated as a class A agricultural water supply. However, the northern portions are designated as a class B agricultural water supply, meaning the natural chemical characteristics of the stream make it unsuitable for agricultural purposes.

Based on the associated-water-quality criteria associated with those beneficial uses, Salt Creek is listed as impaired throughout the study reach (NDEQ 2012 Integrated Report). Specific impairments included E. coli bacteria, ammonia, chloride (in the northern reach), a fish-consumption advisory, an impaired aquatic community, and conductivity. Aesthetic uses were met throughout Salt Creek, and agricultural water supply uses were met in the southern reach. Though a Total Maximum Daily Load (TMDL) has been developed for E. *coli,* TMDLs for the other impairments remain to be completed. As a result, Salt Creek is included as a category 5 stream on the EPA Section 303d list. None of the tributaries within the Salt South Watershed have been designated for specific beneficial uses and thus are not included as part of the EPA Section 303d list. Of course, the quality of water in those tributaries contributes to the quality of water downstream in Salt Creek.

Table 4.2 Geometric means of selected analytes in the Salt South Watershed

	Hickman Br Trib at Wittstruck Rd near Hickman, Nebr.	**Wagon Train Lake Unnamed Trib North Inflow**	**Salt Creek at Roca, Nebr.**	**Salt Creek at Saltillo Rd near Lincoln, Nebr.**	**Salt Creek Trib near S 14th St and Rokeby Rd, Lincoln Nebr.**
Number of samples	3	11	30	1	2
Range of years represented	2013 only	2003-2008	1989-2013	1951	2013 only
pH, water, unfiltered, field, standard units	7.8	--	7.9	[A] 7.4	7.4
Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	619	--	780	[A] 475	412
Dissolved oxygen, water, unfiltered, milligrams per liter	8.2	--	7.9	--	7.4
Suspended solids, water, unfiltered, milligrams per liter	<27.1	560.1	50.1	--	184.4
Hardness, water, milligrams per liter as calcium carbonate	213	--	248	[A] 193	130
Calcium, water, filtered, milligrams per liter	57.2	--	72.2	[A] 56	37.1
Magnesium, water, filtered, milligrams per liter	17	--	16.4	[A] 13	9.1
Sodium adsorption ratio, water, number	1.5	--	1.2	[A] 0.9	0.9
Sodium, water, filtered, milligrams per liter	50.5	--	44.1	[A] 29	23.6
Ammonia, water, filtered, milligrams per liter as nitrogen	<0.03	--	<0.05	--	<0.01
Phosphorus, water, unfiltered, milligrams per liter as phosphorus	0.86	1.2	0.38	--	1.1
Escherichia coli, defined substrate test method (DSTM), water, most probable number per 100 milliliters	307	5,183	1,141	--	995
Copper, water, filtered, micrograms per liter	1.2	--	<1.2	--	2.3
Selenium, water, filtered, micrograms per liter	3.4	--	2	--	1.1
Organic carbon, water, unfiltered, milligrams per liter	19.2	--	8.9	--	32.7
Atrazine, total, micrograms per liter	--	3.8	9.8	--	--
[--, No data; <, less than.]; [A] Not a true geometric mean as only one sample value was available for this analyte					

Table 4.2 Geometric means of selected analytes in the Salt South Watershed

	Salt Cr Trib at S 14th St and Vavrina Blvd, Lincoln, Nebr.	**Salt Cr at Pioneers Blvd at Lincoln, Nebr.**	**Salt Cr at Park Blvd at Lincoln, Nebr.**	**Salt Cr at W South St. at Lincoln, Nebr.**
Number of samples	3	373	1	4
Range of years represented	2013 only	1973-2013	1951	1994-1995
pH, water, unfiltered, field, standard units	7.8	7.9	[A] 7.5	8.1
Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	390	881	[A] 479	1,595
Dissolved oxygen, water, unfiltered, milligrams per liter	8.9	10	--	8.6
Suspended solids, water, unfiltered, milligrams per liter	<17.4	<50.2	--	54.9
Hardness, water, milligrams per liter as calcium carbonate	107	261	[A] 192	297
Calcium, water, filtered, milligrams per liter	32.1	75.3	[A] 53	79.7
Magnesium, water, filtered, milligrams per liter	6.4	19	[A] 15	23.8
Sodium adsorption ratio, water, number	1.4	2	[A] 0.9	9.5
Sodium, water, filtered, milligrams per liter	33.1	81.9	[A] 30	379
Ammonia, water, filtered, milligrams per liter as nitrogen	0.05	<0.1	--	0.08
Phosphorus, water, unfiltered, milligrams per liter as phosphorus	0.12	0.4	--	0.33
Escherichia coli, defined substrate test method (DSTM), water, most probable number per 100 milliliters	679	473	--	--
Copper, water, filtered, micrograms per liter	<1.5	<3.9	--	--
Selenium, water, filtered, micrograms per liter	0.4	<2.2	--	--
Organic carbon, water, unfiltered, milligrams per liter	9	9.4	--	7.7
Atrazine, total, micrograms per liter	--	<0.3	--	--
[--, No data; <, less than.]; [A] Not a true geometric mean as only one sample value was available for this analyte				

Table 4.2 Geometric means of selected analytes in Salt South Watershed

	Salt Cr at A St. at Lincoln, Nebr.	Salt Cr at O St. at Lincoln, Nebr.	Salt Cr at Charleston St. at Lincoln, Nebr.	Salt Cr at S 14th St at Lincoln, Nebr.
Number of samples	1	7	1	35
Range of years represented	1950	1994-2013	1950	1973-1995
pH, water, unfiltered, field, standard units	[A] 7.4	8	[A] 7.3	7.9
Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	[A] 1,050	4,239	[A] 4,080	6,310
Dissolved oxygen, water, unfiltered, milligrams per liter	--	10.3	--	11.5
Suspended solids, water, unfiltered, milligrams per liter	--	37.7	--	20.7
Hardness, water, milligrams per liter as calcium carbonate	[A] 305	338	[A] 328	356
Calcium, water, filtered, milligrams per liter	[A] 89	88.5	[A] 90	91.1
Magnesium, water, filtered, milligrams per liter	[A] 20	28.3	[A] 25	31.1
Sodium adsorption ratio, water, number	[A] 2.8	21.3	[A] 18	26
Sodium, water, filtered, milligrams per liter	[A] 112	899	[A] 761	1,131
Ammonia, water, filtered, milligrams per liter as nitrogen	--	0.15	--	0.14
Phosphorus, water, unfiltered, milligrams per liter as phosphorus	--	0.3	--	0.3
Escherichia coli, defined substrate test method (DSTM), water, most probable number per 100 milliliters	--	795	--	--
Copper, water, filtered, micrograms per liter	--	<1.6	--	--
Selenium, water, filtered, micrograms per liter	--	2	--	--
Organic carbon, water, unfiltered, milligrams per liter	--	8.1	--	9.5
Atrazine, total, micrograms per liter	--	--	--	--
[--, No data; <, less than.]; [A] Not a true geometric mean as only one sample value was available for this analyte				

4.3.2 Naturally Elevated Specific Conductance and Sodium

Perhaps most notable of the water-quality data is the sharp increase in specific conductance and dissolved sodium as Salt Creek flows downstream (to the north). Most of this increase occurs in the northern portions of the watershed, with the geometric mean of sodium samples increasing from 81.9 mg/L at Pioneers Blvd to 1,131 mg/L at the S 14th St Bridge approximately 5.5 miles downstream. In contrast, sodium levels did not vary as greatly from sites upstream of the Pioneers Blvd Bridge. This phenomenon was anticipated given the locations of historical saline wetlands (Figure 4-2) in the watershed and previous literature (Kister and Mundorff, 1963; Farrar and Gersib, 1991; Verstraeten, 1997). The increase is likely attributable to the underlying Dakota aquifer that, in places, has natural geochemical characteristics that are dominated by high sodium and chloride levels (Kister and Mundorff, 1963). Towards the northern portion of the watershed, this aquifer becomes increasingly connected to the surface water system of Salt Creek and its tributaries as indicated by the presence of saline wetlands. As a result, streamflow—and especially baseflow—in the northern portions of Salt Creek is affected by this natural geochemical characteristic.

It makes sense that from the Hickman Branch to Beal Slough, Salt Creek is classified as a Class A agricultural supply rather than a Class B, which is what it is from Beal Slough to Rock Creek. Conductance and salt content increase as the river goes north through Lincoln. Therefore, the Hickman Branch to Beal Slough, which is farther south, has a much lower dissolved sodium content and sodium adsorption ratio. For example, the geometric mean of the sodium adsorption ratio is below two until Salt Creek reaches W South St, where it rises to about ten. This number increases as Salt Creek goes north.

If waters with excess sodium (often characterized by the sodium-adsorption ratio, or SAR) were added to the soil, the sodium might disrupt the soil structure by dispersing clay particles. Such dispersion would act to reduce infiltration conditions of the soil. SARs in the northern portions of Salt Creek are commonly 10 or greater and would be classified as having high sodium hazards if used as irrigation water (Richards, 1954). Therefore, it is appropriate that the northern portion of Salt Creek in the watershed (downstream from its confluence with Beal Slough) is listed as a Class B agricultural water supply that is not conducive to agricultural purposes. In contrast, SARs in the southern portion of Salt Creek (upstream from the confluence of Beal Slough) are typically 2 or less, suggesting that the designation of the stream as a Class A agricultural water supply is appropriate.

4.3.3 Runoff Characteristics

Because of persistent rainfall that occurred throughout the day on November 5, 2013 and November 6th, 2013, wet-weather samples were collected to represent runoff conditions. Though runoff did appear to be present during sampling, the streamflow record suggests that this was a fairly minor event. The addition of historic sampling data added a greater range of streamflows to some of the Salt Creek sites, and the highest sampled streamflow was 5,170 cfs at Roca, NE in 2008. When compiled together these sample data provide information about the characteristics of Salt Creek runoff, especially in the southern portions of the Watershed.

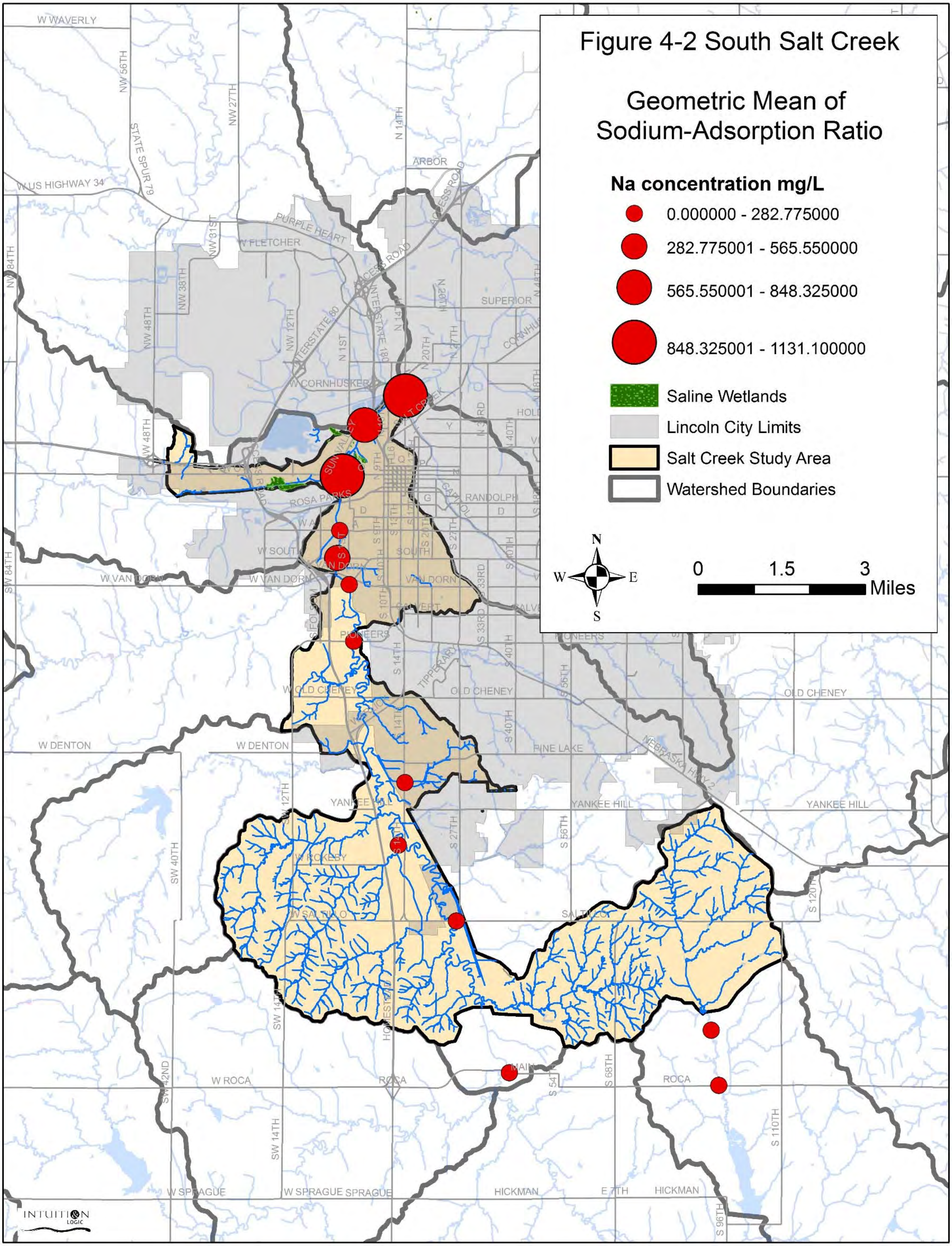
Figure 4-2 South Salt Creek
Geometric Mean of
Sodium-Adsorption Ratio
Na concentration mg/L
0.000000 - 282.775000
282.775001 - 565.550000
565.550001 - 848.325000
848.325001 - 1131.100000
Saline Wetlands
Lincoln City Limits
Salt Creek Study Area
Watershed Boundaries
N
S
E
W
0
1.5
3
Miles
W WAVERLY
W US HIGHWAY 34
W FLETCHER
ARBOR
SUPERIOR
W CORNHUSKER
ROSA PARKS
RANDOLPH
W VAN DORN
VAN DORN
PIONEERS
W OLD CHENEY
OLD CHENEY
W DENTON
PINE LAKE
YANKEE HILL
W ROKEBY
W SALTILLO
SALTILLO
W ROCA
ROCA
W SPRAGUE
SPRAGUE
HICKMAN
NEBRASKA HWY 2
INTUITION LOGIC

Unfortunately, much less is known about runoff characteristics in the tributaries that contribute to Salt Creek within the Watershed. The addition of historical data added 1 tributary site within the Watershed on an unnamed tributary to Wagon Train Lake. However, total suspended solids data for this site suggest that all of the samples were collected during runoff conditions, thereby precluding a comparison to normal conditions.

At all sites, runoff tended to introduce and mobilize sediment in the stream, and some analytes that are typically associated with sediment (such as *E. coli*) increased. Moreover, some analytes that typically increase during runoff (total organic carbon, and atrazine) also increased. In contrast, runoff often reduces the mineral levels in a stream by introducing relatively mineral-free rainwater, and this pattern was generally seen in several of the analytes tested in this study (hardness, calcium, magnesium). Data for some of the other analytes showed less sensitivity to runoff (ammonia, phosphorus, copper, and selenium), which may suggest that the relation to streamflow is weak but also may be the result of inadequate data for detecting such a relation.

4.3.3.1 Total Suspended Solids

At sites where data were available, total-suspended solids (TSS) showed a direct, positive relation with streamflow (Figure 4-3). The trend of the data implies that TSS concentrations are probably higher during larger runoff events. Given that the channel is incised and actively widening, these solids are likely originating both from overland and in-channel erosional processes.

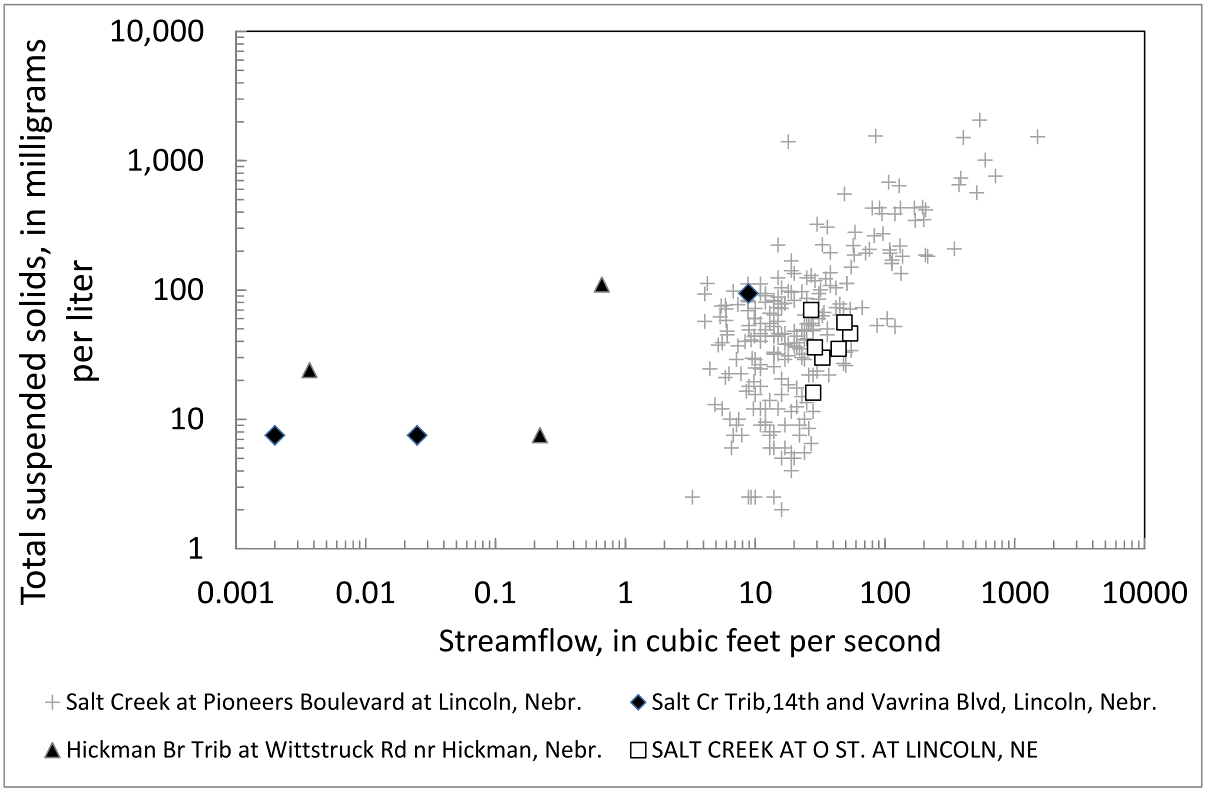

Figure 4-3. Total-suspended solid concentrations increase as streamflow rates increase in the Salt South Watershed.

4.3.3.2 Bacteria

Bacteria levels generally increased during runoff conditions (Figure 4-4). The maximum-sampled *E. coli* concentration was over 24,000 colonies per 100 mL, but—as with TSS—the trend of the data imply that those concentrations may be considerably higher during larger runoff events. Though outside of the Salt South Watershed, sampling data from Salt Creek near Ashland, Nebraska (USGS station number 06805000), show *E. coli* levels going as high as 120,000 colonies per 100 mL (http://nwis.waterdata.usgs.gov/nwis). Curiously, *E. coli* concentrations from the three Hickman Branch Tributary samples did not tend to vary with runoff, though it is probable that additional samples at higher streamflows would have shown otherwise.

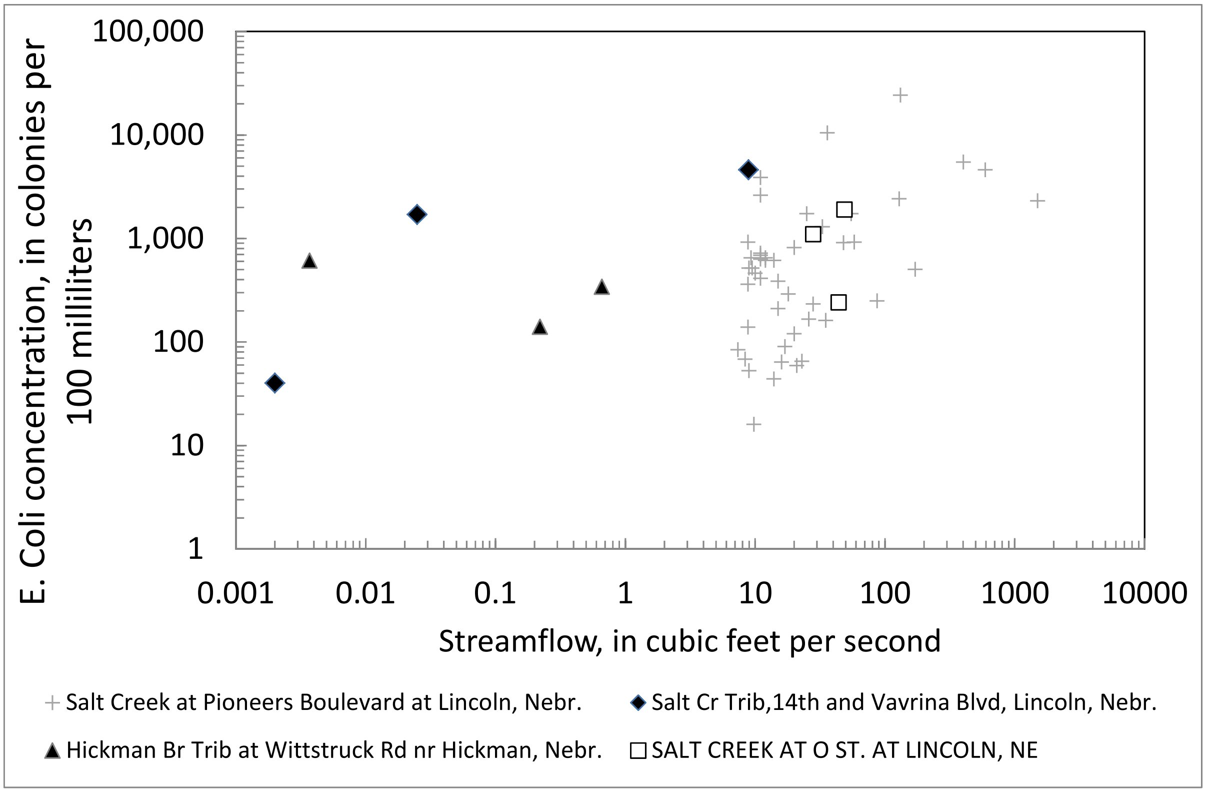

Figure 4-4. *E. coli*. concentrations tend to increase as streamflow rates increase in the Salt South Watershed.

4.3.3.3 Total Phosphorus

Total phosphorus (TP) data did not show a strong relation to streamflow (Figure 4-5). It is somewhat surprising there isn't a stronger correlation given that most phosphorus typically occurs in particulate-organic form or is bound to sediment particles, both of which would be expected to be mobilized during runoff conditions. Though this may be a result of inadequate data to fully define TP characteristics in Salt Creek, it may also suggest that phosphorus levels are less sensitive to variations in runoff.

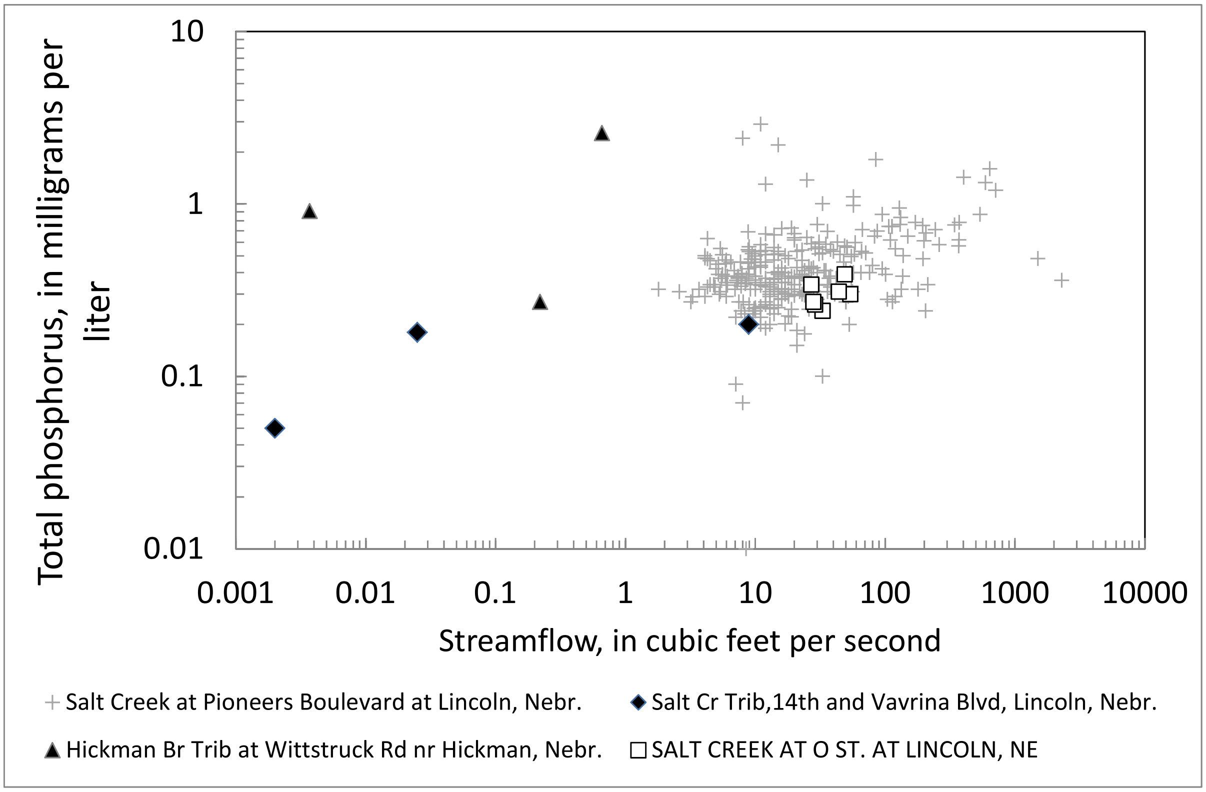

Figure 4-5. Total phosphorus concentrations show no strong relation to streamflows in Salt Creek.

4.3.3.4 Atrazine

Though atrazine was not sampled for this study, historic atrazine data showed a positive relation to streamflow (Figure 4-6). Because atrazine is typically applied to cropland, this suggests that at least some of the stormwater is currently affected by agricultural runoff rather than urban runoff. In addition to its relation to streamflow, atrazine concentrations typically also vary by season, with concentrations peaking in late spring and having their minima during the winter. This seasonal effect is related to the timing of atrazine applications in the region.

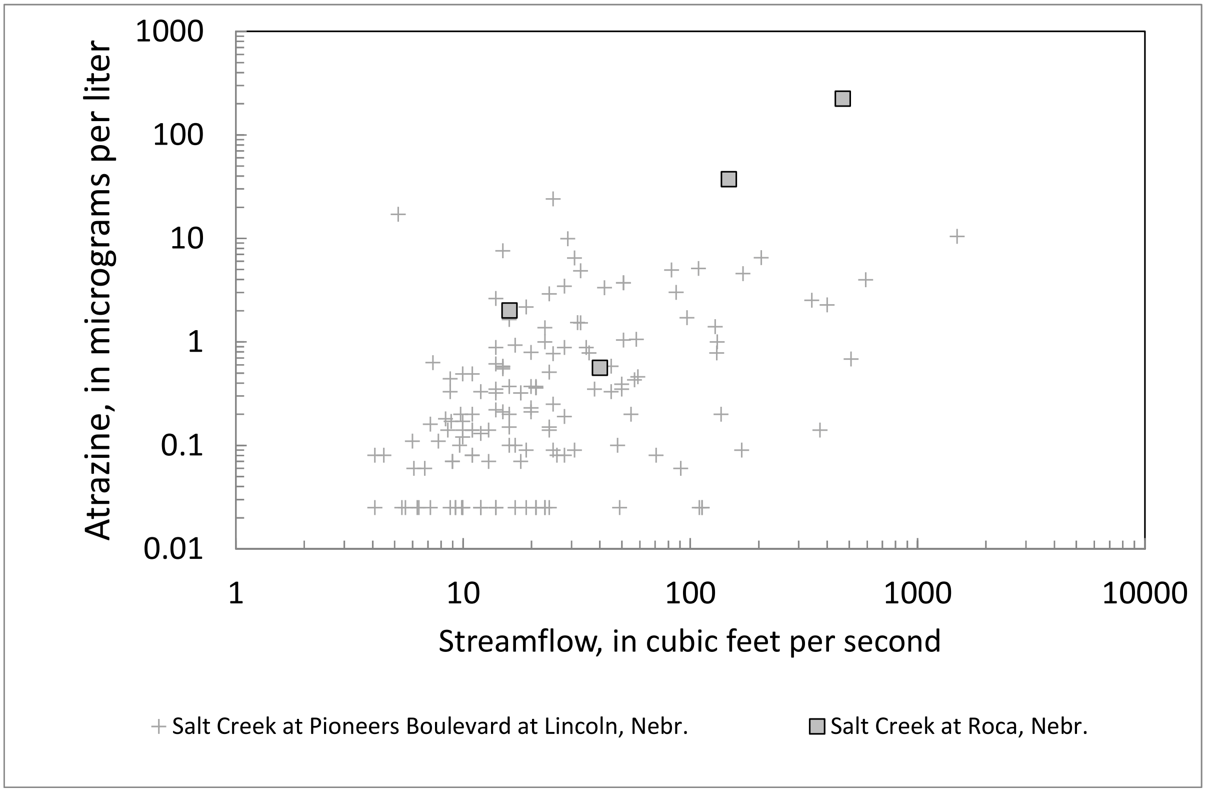

Figure 4-6. Atrazine concentrations tend to increase as streamflow rates increase.

4.4 Managing Stormwater Quality

The Clean Water Act, and specifically the National Pollutant Discharge Elimination System (NPDES) regulates surface-water quality in Lincoln. As part of the NPDES program, the City must apply stormwater best-management practices (BMPs) designed to preserve the quality of its streams and reservoirs. BMPs can be both structural and nonstructural and typically strive to reduce the impacts of stormwater runoff on the receiving water bodies.

The results confirm that stormwater runoff affects the physical and chemical characteristics of the stream. Some of those characteristics may be following natural processes associated with the hydrologic cycle, such as the dilution of minerals during rainfall-runoff. Some of those characteristics may be exacerbated by anthropogenic processes such as erosion, pesticide application, or nutrient enrichment. Consequently, a stormwater management program should consider these processes. A focus on urban BMPs will provide benefits, but will neglect the contributions of agricultural runoff to the water quality. A focus on in-channel processes may neglect the contribution of overland processes.

In this context, a comprehensive program employing multiple types of stormwater BMPs may be most effective at managing the stormwater quality in the Salt South Watershed. Non-structural BMPs such as education, land planning, and enforcement of sediment control provisions will be important for preventing pollution and coordinating BMP implementation in a basin affected by both urban and agricultural runoff. Structural BMPs such as those listed in the City's Drainage Criteria Manual will serve to reduce pollutant loading from overland processes. Capital-improvement projects associated with channel stabilization (and listed in other sections of this report) will likely reduce the amount of sediments (and associated constituents) being mobilized. On their own, each of these BMPs may not provide a measureable benefit to the water quality. However, as more of these BMPs are applied, their cumulative effect may improve the water quality in the South Salt Creek Watershed.