SECTION 4 – TMDL ASSESSMENT

4.1. Introduction

The Nebraska Department of Environmental Quality (NDEQ) Water Quality Division develops and prioritizes a biennial list of "impaired" state waters that do not attain water quality standards for designated uses. This list, commonly referred to as the impaired waters list, is developed in accordance with Section 303(d) of the Federal Clean Water Act (CWA). NDEQ obtains state water data as part of the Nebraska Ambient Stream Monitoring and Basin Rotation Networks. The Ambient Stream Monitoring Program consists of 98 fixed station sites distributed throughout Nebraska's 13 designated river basins, with data collected based on NDEQ's sampling rotation. Typically, the sites are co-located with stream gauging stations. Under this program, monitoring is limited to two or three river basins each year with all 13 basins being (partially) examined in a 5-year period.

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Once a water body is identified as "impaired", states are required to initiate the Total Maximum Daily Load process to address these impairments and assign pollutant load allocations to various sources discharging to the stream. Waste load allocations are assigned to point sources such as permitted wastewater and stormwater discharges (*i.e.,* MS4 permits). Load allocations are assigned to non-point and background sources. A margin of safety is also required. The basic form of a TMDL calculation is:

TMDL (Total Maximum Daily Load) = ΣWLA (Waste Load Allocation) + ΣLA (Load Allocation) + MOS (Margin of Safety)

Pollutant contributions in the waste load allocation component of this calculation are reduced through permit requirements and enforced under National Pollutant Discharge Elimination System (NPDES) permits. Pollutant contributions in the load allocation component are typically reduced through non-structural and structural best management practices (BMPs). Municipal separate storm drainage systems (MS4s) are considered point sources. Background contributions such as natural sources are recognized in the load allocation component. The margin of safety component of the TMDL may be based on an assigned quantitative load (explicit) or on a conservative assumption (implicit). Stated differently, an explicit margin of safety requires waste loads and loads to be reduced to reach a target lower than the stream standard, whereas the target for an implicit margin of safety is typically the stream standard.

The following section provides a description of the current Antelope Creek TMDL, a general comparison of the Antelope Creek TMDL to other TMDLs in Lancaster County and the State, information on the primary constituent of concern (*E. coli*), and information on past constituent of concern (ammonia). A summary is included on the basis used for listing these streams as impaired and a brief discussion of other pollutants of concern.

4.2. Antelope Creek TMDL

Antelope Creek was included in the 2010 Nebraska Surface Water Quality Integrated Report as an impaired water body due to excessive conductivity, copper, selenium and *Escherichia coli* (*E. coli*) bacteria. Data collected by NDEQ from 2002-2005 indicated the following impairments to beneficial uses:

- Primary contact recreation — *E. coli* bacteria
- Aquatic life — ammonia, copper, and selenium
- Agricultural water supply — conductivity, chloride

As a result of these listings, NDEQ developed TMDLs for ammonia and *E. coli* in 2007 (NDEQ 2007). No TMDLs were developed for conductivity, selenium, and copper due to uncertainty associated with the limited data set and the potential for changes to the designated uses through completion of a Use Attainability Analysis. In 2010, NDEQ removed ammonia from the 303(d) list and added chloride. Ammonia was removed from the Antelope Creek sampling for this project because recent NDEQ ambient stream monitoring data and data from the first round of Antelope Creek sampling indicated that the ammonia levels previously reported for Antelope Creek were no longer above the water quality criteria. The water quality goals for the TMDL are currently being met for ammonia. As a result, the primary focus of this Basin Plan with regard to existing stream impairments is *E. coli*.

It is important to note that there are no municipal wastewater treatment plant (WWTP) discharges to Antelope Creek, so the primary focus from a waste load allocation perspective is the two stormwater NPDES permits in the basin, which include the City and University of Nebraska–Lincoln (UNL). Two industrial discharges had been permitted but are no longer operational and do not discharge to the Creek. No non-point sources of pollution are specified in the TMDL, although wildlife is identified as a natural source of *E. coli*. Although many TMDLs use an implicit margin of safety in their calculations, the Antelope Creek TMDL includes a clearly defined explicit margin of safety that reduces the water quality target below the stream standard by 10%. For example, the water quality objective for the *E. coli* seasonal geometric mean in the Antelope Creek TMDL is 113 colony forming units per 100 milliliters (cfu/100 mL); which is 10% below the NDEQ's TMDL stream standard of 126 cfu/100 mL.

4.3. State and Local Watershed TMDLs

As of 2010, NDEQ had completed 12 TMDLs for lakes (Table 4-1) and 15 TMDLs for streams (Table 4-2). Multiple stream segments (*e.g.,* 5 to 10 segments) were often included within a single TMDL, so the number of stream segments in the state impaired by *E. coli* with TMDLs completed is about four times higher, totaling approximately 60 segments. Based on the 2010 NDEQ Integrated Report, nearly 70 additional water body segments are listed as impaired for *E. coli*, but TMDLs have not been developed. These *E. coli* listings account for about half of the Nebraska stream impairments requiring TMDLs.

Lancaster County has five stream TMDLs and three lake TMDLs, including Holmes Lake. Antelope Creek and the Lower Platte River (eight segments) have *E. coli* TMDLs, both of which were completed in June 2007. Salt Creek, Wahoo Creek, Deadmans Run, and Oak Creek segments are included in the Lower Platte River *E. coli* TMDL. Segments in the vicinity of Lincoln are shown on Figure 4-1. NDEQ has completed TMDLs for all of the *E. coli* listed stream segments in the Lower Platte River Basin. Adjacent river basins with *E. coli* TMDLs include the Big Blue River Basin and the Nemaha River Basin, both of which include multiple stream segments in each basin TMDL.

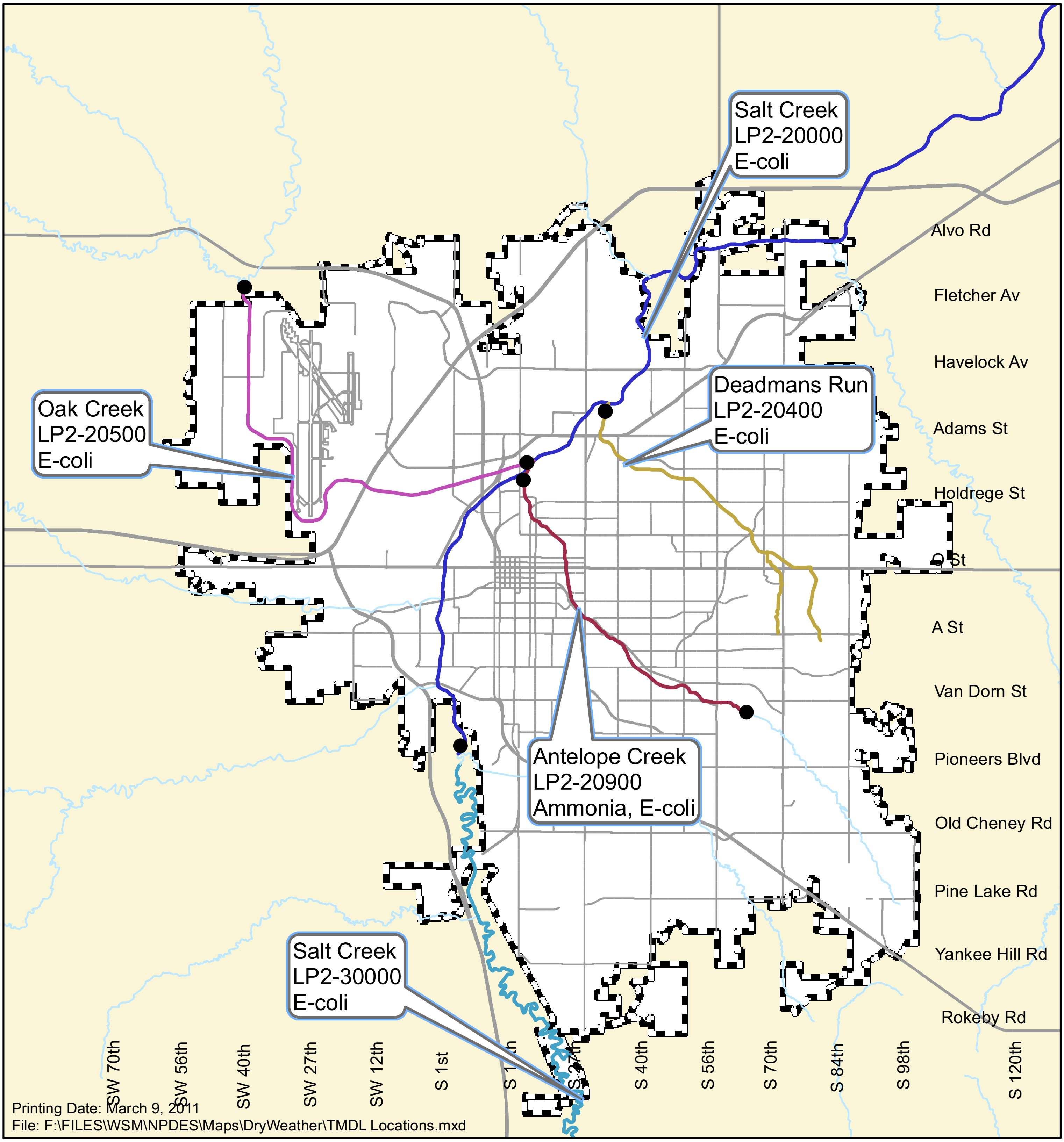
Table 4-1. TMDLs Completed for Nebraska Lakes (NDEQ 2010)

Lake Name	Location (county)	Parameters	Date
Big Indian Lake	Gage County	Sediment and Phosphorus	September-09
Carter Lake	Douglas County	Algae and Turbidity	June-07
Holmes Lake	**Lancaster County**	Sediment and Phosphorus	June-03
Iron Horse Trail Lake	Pawnee County	Phosphorus and Sediment	December-05
Johnson Lake	Gosper County	Fecal coliform	August-04
Kirkman's Cove	Richardson County	Phosphorus	September-02
Lake Ogallala	Keith County	Sulfides and Inst. Oxygen Demand	June-07
Fremont 20	Dodge County	Phosphorus	June-07
Standing Bear Lake	Douglas County	Sediment and Phosphorus	June-03
Wagon Train Lake	**Lancaster County**	Sediment and Phosphorus	September-02
Yankee Hill	**Lancaster County**	Sediment and Phosphorus	August-02
Zorinsky Lake	Douglas County	Sediment and Phosphorus	September-02

Source: Nebraska Department of Environmental Quality 2010

Figure 4-1. State of Nebraska NDEQ TMDL Listed Water Bodies for Lincoln/Lancaster Co. Area

Public Works & Utilities



CITY OF LINCOLN
NEBRASKA
MAYOR CHRIS BEUTLER

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Miles

State of Nebraska NDEQ 2010 - TMDL Listed Water Bodies for Lincoln/Lancaster Co. Area

** Not inclusive of all pollutants of concern*

Legend

Major Streams

TMDL

- Other Streams
- LP2-20000
- LP2-20400
- LP2-20500
- LP2-20900
- LP2-30000

Table 4-2. TMDLs Completed for Nebraska Streams

Stream	Location (county or stream segments)	Parameters	Date
Antelope Creek	LP2-20900, **Lancaster**	*E. coli*; Ammonia	June-07
Middle Creek	LP2-21100, **Lancaster** and Seward	Atrazine	June-07
Shell Creek	LP1-20700, Antelope, Boone, Colfax, Madison and Platte	Atrazine	June-07
Big Blue	Multiple Segments: Gage, Pawnee, Jefferson, Saline, **Lancaster**, Fillmore, Clay, Adams, Seward, York, Hamilton, Hall, Butler, Polk	*E. coli*	February-05
Elkhorn River Basin	Multiple Segments: Antelope, Brown, Boone, Burt, Cedar, Colfax, Cumming, Dixon, Dodge, Douglas, Garfield, Holt, Knox, Madison, Platte, Rock, Stanton, Thurston, Washington, Wayne and Wheeler Sarpy	*E. coli*	September-09
Little Blue River Basin	Multiple Segments: Jefferson, Saline, Fillmore, Clay, Nuckolls, Adams, Thayer, Webster, Kearney, Franklin	*E. coli*	February-05
Loup River Basin	Multiple Segments: Arthur, Blaine, Boone, Brown, Buffalo, Cherry, Custer, Dawson, Garden, Garfield, Grant, Greeley, Holt, Hooker, Howard, Logan, Loup, McPherson, Merrick, Nance, Platte, Rock, Sherman, Sheridan, Thomas, Valley, Wheeler	*E. coli*	December-02
Lower Platte River Basin	Multiple Segments: Boone, Butler, Cass, Colfax, Dodge, Douglas, **Lancaster**, Madison, Platte, Sarpy, Saunders, Seward	*E. coli*	June-07
Middle Platte	Multiple Segments: Platte, Polk, Nance, Merrick, Hamilton, Howard, Hall, Adams, Kearney, Buffalo, Phelps, Gosper, Dawson, Custer, Frontier, Logan, Lincoln, McPherson	Fecal coliform	April-03
Nemaha Basin	Multiple Segments: Cass, Gage, Johnson, **Lancaster**, Nemaha, Otoe, Pawnee and Richardson	*E. coli* & Atrazine	June-07
Niobrara	Multiple Segments: Antelope, Boyd, Box, Butte, Brown, Cherry, Dawes, Holt, Keya Paha, Knox, Morrill, Rock, Sheridan and Sioux	*E. coli*	December-05
North Platte	Multiple Segments: Lincoln, McPherson, Keith, Arthur, Garden, Sheridan, Cheyenne, Morrill, Kimball, Banner, Scottsbluff, Sioux	*E. coli*	September-03
Papillion Creek	Multiple Segments: Douglas, Sarpy and Washington	*E. coli*	September-09
Republican	Multiple Segments: Chase, Dundy, Franklin, Frontier, Furnas, Gosper, Harlan, Hayes, Hitchcock, Kearney, Keith, Lincoln, Nuckolls, Perkins, Phelps, Red Willow, Webster	*E. coli*	February-05
White River	Segment WH1-20000, Dawes, Sheridan and Sioux	*E. coli*	December-05

Source: Nebraska Department of Environmental Quality 2010

A comparison of the Antelope Creek and Lower Platte River Basin *E. coli* TMDLs was completed to assess whether similar approaches were used for development of the TMDLs and to identify common factors that may be contributing to elevated *E. coli* in these basins. Multiple stream segments in the Lower Platte River Basin were addressed in the Lower Platte River Basin TMDL, whereas Antelope Creek is addressed in a separate TMDL. Table 4-3 summarizes several key characteristics for the relevant stream segments, followed by discussion of several of these characteristics.

Table 4-3. Summary of *E. coli* Data Providing Basis of Lower Platte Basin *E. coli* TMDLs

Segment Location	Dominant Land Use	WWTPs: # Discharging to Stream/# in Basin (Descp. if > 0.5 cfs)[1]	Number of Samples[2]	Seasonal Geometric Mean (#/100 mL)	Targeted Reduction	Target (#/100 mL)
Antelope Creek at Lincoln	Urban	0/0	20[3]	3,433	97%	113
Dead Man's Run at Lincoln	Urban	0/0	20	1,404	92%	112
Salt Creek at Lincoln	Urban	2/8 NE Lincoln (15.47 cfs) Theresa St. (44.87 cfs)	20	432	74%	112
Oak Creek at Lincoln	Mixed (Airport/Indust/ Open)	0/1	20	389	71%	113
Salt Creek at Pioneers Blvd: Lincoln	Mixed (Wilderness Park/Open/Res.)	0/2	20	458	76%	110
Platte River at Louisville	Agricultural	5/10	22	314	64%	113
Platte River at North Bend	Agricultural	3/9 Cargill Meats (4.25 cfs) Schuyler (1.08 cfs)	22	750	85%	113
Salt Creek at Greenwood	Agricultural	2/5	21	718	85%	108
Wahoo Creek at Ashland	Agricultural	0/6 Wahoo (1.08 cfs)	22	531	79%	111

Table Notes:
[1]In some cases, a wastewater treatment plant (WWTP) may be present in the watershed, but does not discharge directly to the stream segment.
[2]Data forming the basis of the Antelope Creek and Lower Platte River Basin *E. coli* TMDLs was collected during 2004 under the NDEQ rotating basin monitoring program.
[3]Number of *E. coli* samples identified in the Antelope Creek TMDL is 20; however, 21 samples are present in the NDEQ electronic data set. This minor discrepancy does not substantively affect conclusions regarding *E. coli*.

Key observations resulting from this comparison include:

- Both Antelope Creek and Lower Platte River Basin TMDLs follow similar protocols using Load Duration Curves to target *E. coli* load reductions. This approach is a tool that associates *E. coli* loads with flow conditions and helps target whether the source loading is due to point or nonpoint sources of pollution. This tool provides general information on how to partition the TMDL between waste load allocations and load allocations, but does not provide a detailed assessment of specific sources of pollutant loading within these categories. The Antelope Creek Load Duration Curve shows elevated *E. coli* under both high and low flow conditions, suggesting that nonpoint sources under base flow conditions are likely a contributing factor.
- Both TMDLs are based on relatively limited data sets, with comparable numbers of samples (20-22) for each stream segment addressed.
- Both TMDLs use an explicit margin of safety approach, which results in a target below the stream standard (*e.g.,* 113 cfu/100 mL as opposed to 126 cfu/100 mL). WWTP NPDES permits were allocated based on the stream standard.
- Substantial reductions in *E. coli* are targeted for most of the listed stream segments with reductions in the 64 to 97 percent range.

- In-stream and environmental factors affecting bacteria die-off or growth are not discussed in the TMDLs.
- No combined sewer overflows or sanitary sewer overflows are identified as affecting any of these streams.
- Antelope Creek does not receive WWTP discharges, unlike several of the stream segments in the Lower Platte River TMDL. Based on additional research by EA, the only two permitted industrial discharges noted in the Antelope Creek TMDL are no longer occurring.
- The Antelope Creek drainage basin is located within an urbanized area, whereas several portions of the Lower Platte River TMDL are in undeveloped areas.
- The Lower Platte River TMDL assigns load allocations for non-point sources, whereas non-point sources are not included in the Antelope Creek TMDL. Although wildlife is briefly mentioned in the Antelope Creek TMDL as a natural source, the primary thrust of the TMDL is focused on the MS4 permits, with non-point sources identified as negligible. In the City of Lincoln's MS4 discharge permit, a municipal separate storm drainage system is defined as "a conveyance or system of conveyances including but not limited to roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels designed or used for collecting or conveying stormwater." "Point-source discharges of municipal stormwater and other authorized flows" from these sewers or systems of sewers are the focus of regulation in the discharge permit. It is important to recognize that in Lincoln and other urban areas, there are also sources of pollution to the stream that are not discharged from such stormwater conveyance systems. For example, birds and squirrels that nest in the tree canopy or bridges along the riparian corridor of the stream channel may be sources of *E. coli* that do not originate from the City's storm drainage system. As other examples, many urban areas have foxes, coyotes, raccoons and other mammals that frequent waterways and may contribute to *E. coli* loads. These diffuse sources that are not part of the stormwater conveyance system are best characterized as non-point sources of *E. coli*. Based on observations along Antelope Creek, natural sources (particularly birds) are expected to be potentially significant factors affecting *E. coli* concentrations on Antelope Creek; however, these factors are not discussed in the Antelope Creek TMDL. Additional monitoring is needed to assess the degree to which these nonpoint source factors are affecting Antelope Creek *E. coli* concentrations.
- Land uses among the stream segments vary from agricultural to urban and include segments with and without WWTP discharges to the stream. Several qualitative observations (*i.e.,* without statistical testing) can be made based on a comparison of the factors in Table 4-3. Urban land uses appear to be associated with the highest *E. coli* concentrations, with Antelope Creek and Dead Man's Run having the highest *E. coli* recreation season geometric mean concentrations (1,400-3,400 cfu/100 mL) and other impaired stream segments having geometric mean concentrations in the 300-800 cfu/100 mL range. Presence of WWTP discharges does not appear to strongly affect observed *E. coli* values.
- Basic implementation plans are provided in each TMDL that identify existing regulatory programs as the primary path toward reducing *E. coli* exceedances. For example, the implementation plan sections reference existing NPDES WWTP and stormwater permits, Confined Animal Feeding Operation regulations, and Section 319 nonpoint source management program grant opportunities. Stormwater is addressed in the context of EPA (2002) guidance, which focuses on use of municipal stormwater programs to reduce pollutant loading.

In summary, comparable approaches for development of *E. coli* TMDLs were used by NDEQ for Antelope Creek and Lower Platte River Basin. For the Antelope Creek TMDL, additional exploration of non-point source contributions to *E. coli* is needed, and being completed as part of this Basin Plan. Additionally, the conservative mass balance approach to the TMDL (*e.g.,* not accounting for bacteria die-off) could provide a basis for use of an implicit margin of safety, as opposed to an explicit margin of safety, which has the effect of lowering the stream standard target.

4.4. Pollutants

An overview of the primary pollutant of concern (*E. coli*) for Antelope Creek, including why the pollutant is regulated is discussed below. Other constituents of potential concern are also briefly described including ammonia, which was listed in the 2008 TMDL but is no longer considered a concern based upon the 2010 Nebraska Surface Water Quality Integrated Report. Each pollutant's relationship with land uses in Antelope Creek is further described in SECTION 6 - POLLUTION SOURCES AND CONTROL STRATEGIES.

4.4.1 *E. coli*

EPA uses *E. coli* and enterococcus as indicators of fecal contamination of receiving waters, with *E. coli* recommended for use in freshwater environments. These fecal indicator bacteria are present in the intestines of warm-blooded animals and are easier to identify and enumerate in water quality samples than the broad range of pathogens in human and animal feces. Presence of the *E. coli* subgroup indicates that some degree of fecal contamination to the stream has occurred and that water quality conditions may pose increased risk to human health for those swimming or recreating in a water body. The geometric mean standard of 126 cfu/100 mL of *E. coli* is based on an accepted risk level of eight swimmer illnesses per 1,000 exposures.

In total, 12 of Nebraska's 13 primary watersheds have water bodies that are affected by *E. coli* (or fecal coliform, spanning both rural and agricultural land uses. This statewide perspective is important because it shows that elevated *E. coli* is a common phenomenon in Nebraska streams and that is not limited to urban areas. Nationally, pathogens (as evidenced by elevated fecal indicator bacteria) were the top cause of stream impairments, with over 10,000 stream segments identified as impaired.

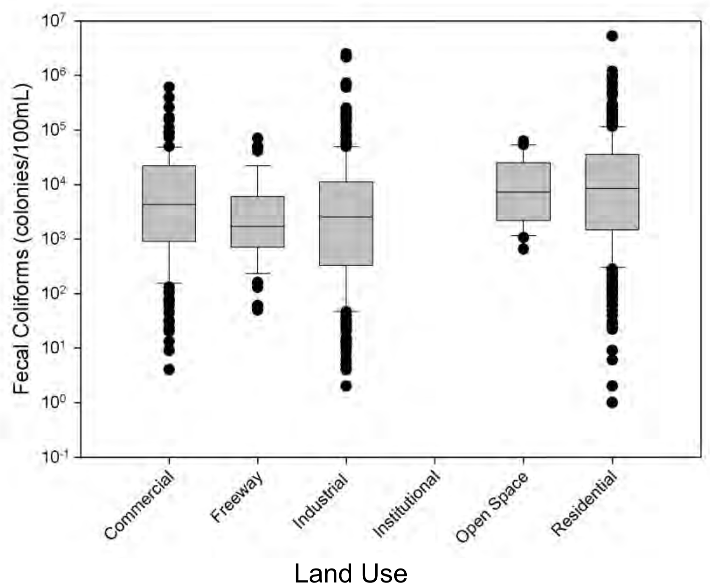
Sources of fecal indicator bacteria in streams vary widely and include animal, human and environmental sources such as:

- Illicit discharges through improper connections to the municipal storm drainage system (*e.g.,* inadvertent plumbing connections of sanitary wastewater to the storm drainage system).
- Municipal and industrial wastewater treatment facilities without adequate treatment processes or improperly functioning treatment systems.
- Malfunctioning on-site wastewater systems.
- Sanitary sewer overflows, combined sewer overflows and sewer line break discharges.
- Urban stormwater runoff, including rain and snowmelt.
- Urban dry weather discharges such as power washing of impervious surfaces with bird droppings and lawn irrigation runoff that collects bacteria from gutters.
- Urban wildlife that inhabits storm drainage systems such as raccoons and rats, along with other wildlife.
- Bird nesting areas under bridges overhanging streams and direct use of water bodies by birds, both in the water and on lawn areas directly adjacent to water bodies.
- Wildlife and domestic animal use of vegetated or open space areas such as parks, golf courses, and urban lawns.
- Agricultural runoff from crops, pasture and confined animal feeding operations (CAFOs).
- Unique source areas with higher animal densities such as zoos, stock show arenas, dog parks, etc.
- Environmental growth and persistence of *E. coli* in stream sediments and algae.

Environmental sources of bacteria have gained increasing attention in recent years. For example, Skinner et al. (2010) summarize recent research indicating that biofilms (*i.e.,* the "slime layer") in storm drainage systems provide a safe environment for enhanced bacterial replication, supply nutrients and water for biofilm bacteria, and offer protection against microbial predators, ultraviolet (UV) light, drying, and disinfectants (citing research by Coghlan 1996, Costerton et al. 1995, Donlan and Costerton 2002, Donlan 2002). Environmental sources of fecal indicator bacteria such as bacteria in sediments present in outfalls and streambeds have also received attention in various studies (*e.g.,* Byappanahalli et al. 2003; Byappanahalli et al., 2006; Davies et al. 1995; Monroe 2009). Other studies have shown plant sources such as decaying kelp along beaches serving as the "perfect incubator for bacterial growth" (Kolb and Roberts 2009).

Regardless of whether the source is natural or human-caused, fecal indicator bacteria concentrations in urban stormwater are typically well above primary contact recreation stream standards, regardless of the land use (Figure 4-2) (Pitt, Maestre and Morquecho 2004).

Figure 4-2. Box and Whisker Plots of Fecal Coliform in Stormwater Data



Note: Primary Contact Recreational Standard for Fecal Coliform =200/100 mL
(Source: Pitt, Maestre, and Morquecho 2004)

To target source controls, more detailed evaluation of sources or activities within various land uses is typically needed, and is discussed further in SECTION 6 – POLLUTANT SOURCES AND CONTROL STRATEGIES. Although some of these sources can be reasonably controlled (*e.g.,* wastewater discharges, illicit connections), other sources are much more difficult to control such as raccoons and other animals in storm drainage systems, beavers, wildlife in open space areas, birds on bridges, and stream and storm drainage system sediments and biofilms. When exploring source of fecal contamination that pose risks to human health, stormwater managers should also be aware that although significant concentrations of fecal indicator organisms are nearly ubiquitous in urban drainage, the relationship between fecal indicators and pathogens is unclear. For example, Schroeder et al. (2002) investigated the presence of human pathogens in urban storm drains in California and concluded, "Pathogens can be found in urban drainage, but there does not appear to be a relationship between the presence of pathogens and the concentration or presence of indicator organisms." (Note: most of the currently available existing epidemiological data are oriented toward contamination from sanitary wastewater sources, as opposed to stormwater sources.)

Currently, water quality criteria do not differentiate risks to human health due to sources of fecal indicator bacteria. Expert panels convened by EPA (2007) and the Water Environment Research Foundation (WERF 2009) have generally agreed that human sources of bacteria are expected to pose a greater health risk than animals and environmental sources, but have also recommended additional research to better quantify this risk. In *Review of Zoonotic Pathogens in Ambient Waters*, EPA (2009) concludes "Contamination of recreational waters with feces from warm-blooded animals poses a risk of zoonotic infection of humans with some of the pathogens in those waters. Although the risk and severity of human illness due to contamination with animal feces and zoonotic pathogens is most likely lower than the risk and severity of illness from treated or untreated human sewage, currently available data are insufficient to quantify the differences." Consequently, EPA requires both natural and human-caused sources of fecal indicator bacteria to be addressed unless an epidemiological study has demonstrated that non-human sources do not pose an increased risk to human health beyond the allowed 8 swimmer illnesses per 1,000 exposures for freshwater settings.

Understanding sources of bacteria is important in selecting appropriate BMPs targeted to these sources. Managing the source should be the first strategy implemented. A variety of guidance and techniques exist for conducting bacteria source tracking, ranging from relatively straightforward illicit discharge screening (CWP and Pitt 2004) to complex microbial source tracking (MST) studies (EPA 2005; WERF 2007). As one example, some communities have had success using quantitative polymerase chain reaction (QPCR) methods for human source

Bacteroides. EPA's Recreational Water Quality Criteria website provides additional information on these techniques (http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/health/recreation/index.cfm).

Data Used to Determine *E. coli* Impairment

The Antelope Creek *E. coli TM*DL is based on *E. coli* data collected by NDEQ in the Lower Platte River basin in 2004. The data set included 21 *E. coli* samples located at "Antelope Creek at State Fair" (Station SLP2ANTLP104) on Antelope Creek. The reported values ranged from 164 to >24,192 cfu/100 mL, with a calculated recreation season geometric mean of 3,163 cfu/100 mL. All sample densities exceeded the 126 cfu/100 mL water quality standard, as well as the 113 cfu/100 mL TMDL target. Additionally, all but one sample exceeded the 576 cfu/100 mL single sample allowable density for infrequently used recreational waters as specified in the Nebraska Water Quality Standards (Title 17, Chapter 4). NDEQ has collected additional data since completion of the TMDL that also show elevated *E. coli* densities.

Although this available data set was adequate for the purposes of identifying the stream segment as impaired for *E. coli*, the single monitoring station on the stream is not adequate to identify sources of *E. coli* or strategies to reduce *E. coli* loading to Antelope Creek. Additionally, the Load Duration Curve in the Antelope Creek TMDL shows exceedances under both high and low flow conditions (NDEQ 2007), therefore elevated *E. coli* on Antelope Creek cannot be simply considered a stormwater issue. To better understand sources of *E. coli* within the basin, additional sampling was included in the development of the Basin Plan. The results of this additional sampling are discussed in SECTION 5 - WATER QUALITY MONITORING.

4.4.2 Ammonia

EPA has established Ambient Water Quality Criteria for Ammonia due to toxicity to fish (EPA 1999). Early life stages of fish are more sensitive than juveniles or adults; therefore, effects are more likely to occur during seasons when early life stages are present. Toxicity of ammonia is dependent on ionic composition, pH, and temperature, with currently applicable EPA criteria calculated based on pH and temperature and applied to total ammonia (EPA 1999). The ionic composition of total ammonia includes the ammonium ion ($NH4^{+}$) and un-ionized ammonia (NH3), with water quality criteria prior to 1999 focusing on the more toxic un-ionized ammonia form. NDEQ water quality standards are based on total ammonia, consistent with currently applicable EPA criteria.

In "CADDIS: The Causal Analysis/Diagnosis Decision Information System", EPA (2010) describes common sources of elevated ammonia in water bodies:

- Impoundments: Impoundment of water may contribute to elevated ammonia concentrations due to lack of turbulence and mixing, which decrease volatilization of ammonia, resulting in higher ammonia concentrations downstream. Thermal stratification in impoundments can lead to higher concentrations of ammonia in the hypolimnion which, with bottom-release dams, can result in increased ammonia in downstream waters.
- Municipal waste treatment plants: Municipal waste treatment plants without adequate permit limits to control ammonia or treatment plant upsets malfunctions or bypasses due to combined sewer overflows (CSOs).
- Septic seepage and failed package plants: Seepage from failed septic tanks or their leach fields, and discharges from poorly–functioning package sewage treatment plants may contribute significant amounts of ammonia to streams and lakes.
- Industrial point source: Certain industries release ammonia as a byproduct in their waste stream. Although ammonia is regulated in discharge permits for such facilities, increased ammonia concentrations exist where the original system design is inadequate or problems in operation lead to inadequately treated discharges. This is especially an issue for industries that produce ammonia, animated organic matter, or other nitrogenous wastes such as food processing (*e.g.,* poultry, livestock, or seafood), pharmaceutical manufacturing (*e.g.,* fermentation processes), paper mills, and flue gas treatment in coal-fired power plants.
- Agricultural and urban runoff: Runoff and leachate from agricultural, recreational (*e.g.,* golf courses), or residential fertilizer use can directly increase the amount of ammonia in surface water.
- Manure application: Manure containing ammonia and other nitrogenous compounds often is spread on fields and then washed into streams and other water bodies by rain or snow melt. Grazing livestock spread urine and manure on pastures and, where they have access to streams, they apply urine and manure directly to water.

- Concentrated animal feeding operations: Runoff from feedlots and other concentrated animal feeding operations can contain high levels of ammonia and other nitrogenous compounds.
- Aquaculture: Drainage from fish and shrimp farms is high in ammonia if not properly treated.
- Landfills: Leachate from landfills may contain high ammonia concentrations (Mancl and Veenhuizen 1991).
- Atmospheric sources: These sources include NH3 originating from agricultural practices and nitrogen oxide emissions from automobiles and industry (NOAA 2000). These are regionally important sources, but they seldom are indicative of particular impairments.
- Riparian devegetation: The removal of vegetation from the banks of surface waters increases surface water runoff and water temperature and decreases woody debris input. Increased surface water runoff may increase the amount of ammonia directly entering the water body. Increased water temperature enhances the toxicity of ammonia. Reduced turbulence from less woody debris may decrease volatilization and oxygenation.
- High plant production: High algal or plant production can decrease ammonia by assimilation, increase ammonia by nitrogen fixation, or increase pH toxicity due to uptake of CO2, resulting in a shift to more unionized ammonia.

With regard to ammonia concentrations in urban stormwater, Pitt (2005) reports median ammonia concentration of 0.32 mg/L for residential areas, 0.50 mg/L for commercial areas and 0.18 mg/L for open space (non-urban) areas. These concentrations are well below typical calculated total ammonia limits for warm water streams.

In the context of Antelope Creek, no municipal or industrial point sources or animal feeding operations are present and urban stormwater is not typically a major source of ammonia. The occasionally elevated concentrations of ammonia in Antelope Creek may be associated with sporadic sources such as fertilizer application or stagnant water in the stream during low flow conditions. Elevated ammonia has not been identified as an issue at Holmes Lake; therefore, it is not expected to be a significant source of ammonia in the stream.

Data Used to Determine Ammonia Impairment

As is the case for *E. coli*, NDEQ has collected ammonia samples from Antelope Creek as part of the NDEQ Ambient Water Quality Monitoring Network, with grab samples for ammonia collected twice per month during April through September. The Antelope Creek TMDL was based on data collected from 2002 through 2005, which included total ammonia values ranging from 0.08 to 10.07 mg/L. Exceedances of both chronic and acute standards occurred, with 13 out of 64 results exceeding the chronic water quality limits for Antelope Creek. Streams are considered impaired for aquatic life in Nebraska if more than 10 percent of the samples exceed the acute or chronic criteria. Total ammonia stream standards are calculated for each sampling event based on the corresponding ambient pH and temperature conditions present at the time of sample collection. NDEQ collected 29 additional ammonia samples in 2009, with reported total ammonia concentrations ranging from 0.17 to 0.929 mg/L, with none of the reported concentrations exceeding water quality standards. These recent data, which show consistently low ammonia concentrations, suggest that ammonia may no longer be a constituent of concern for Antelope Creek, with elevated concentrations primarily occurring more than 8 years ago.

4.4.3 Other Constituents of Concern

In the Antelope Creek TMDL, copper, selenium and conductivity are identified as potential pollutants of concern, but lacking adequate data for determination of impairment or development of TMDLs. All of these constituents, as well as chloride, are identified in the 2010 Integrated Report as causing impairment of designated beneficial uses (NDEQ 2010). A brief description of each of these constituents follows.

Copper

As described in the Antelope Creek TMDL, the basis for listing Antelope Creek as impaired for copper was 4 of 14 samples exceeding the chronic water quality criteria (NDEQ 2006). Subsequent review of the data revealed 6 of the 14 samples being labeled with an “M” remark code. The “M” code is defined as inconclusive analysis due to matrix interference and suggests the sample be re-collected. NDEQ has made the decision to discard these data; however, the assessment procedures did not explicitly allow exclusion of such data. After removing these data points, the remaining data set had only eight samples with two of those exceeding the stream standard. The assessment of waters with less than 10 data points with one or two values exceeding criteria are considered Category 3 water bodies—insufficient information for a listing determination. Thus, NDEQ determined that no

TMDL was needed and indicated that the correction would be made in the 2008 Integrated Report; however, review of the 2010 Integrated Report still shows the stream as being listed for copper (NDEQ 2010).

Copper is an abundant naturally occurring trace element found in the earth's crust that is also found in surface waters. Copper is a micronutrient at low concentrations and is essential to most plants and animals. At higher concentrations, copper can be toxic to aquatic life depending on the hardness of the stream (*i.e.,* concentrations are more toxic at low hardness values). Industries with copper-bearing discharges include manufacturers of leather and leather products, fabricated metal products, and electric equipment, as well as mining. Municipal effluents may also contribute additional copper loadings to surface waters. Copper is also found in municipal stormwater runoff and has been attributed to the erosion of automobile brake lining material. In Antelope Creek, copper sources would most likely be associated with automobile sources.

Selenium

In the Antelope Creek TMDL, NDEQ notes that several selenium values were labeled with the "M" remark code, similar to copper. Once the remarked data were removed, only seven data points remained with three values exceeding the water quality standards. Chronic and acute stream standards for selenium are 5 ug/L and 20 ug/L, respectively. These standards are provided for protection of aquatic life. Based on the assessment procedures utilized by NDEQ, the data set is suitable for the identification of the impairments; however, the data set is not sufficient to complete the TMDL. Additionally, NDEQ noted forthcoming revisions of selenium criteria based on fish tissue concentrations (EPA 2004). Because the EPA selenium criteria revision was still in draft form and results of the assessment of Antelope Creek selenium using the new criteria had not been completed, NDEQ decided to delay the development of a selenium TMDL until the criteria are finalized. NDEQ further noted that Antelope Creek would remain in Category 5 as impaired by selenium in the Integrated Report. Review of the 2010 Integrated Report still shows the stream as being listed for selenium (NDEQ 2010). Three additional samples collected by NDEQ in 2009 exceeded the chronic selenium criteria but fell below the acute criteria.

Selenium is a naturally occurring element that can be toxic to fish, and birds that consume fish when selenium concentrations exceed water quality criteria. High levels (>0.05 mg/L) of selenium can also cause impacts to livestock such as loss of hair in the mane and tail in horses as well as hoof sloughing. Cattle may have a rough hair coat and exhibit symptoms such as reduced reproductive performance, poor weight gain, or hoof or horn changes or loss and lameness can result in advanced cases. Antelope Creek is classified as an Agricultural B stream. This classification has no standard for acute or chronic levels of selenium.

Elevated selenium concentrations can occur as a result of natural or anthropogenic conditions. In the western U.S., elevated selenium in streams is often due to naturally occurring geologic sources, particularly where streams are gaining flows from groundwater in contact with these geologic formations, or where irrigation had has caused leaching of selenium from these geologic sources. Anthropogenic sources of selenium may also include coal ash piles, petroleum refinery effluents, and runoff or discharges from certain mining activities. In the case of Antelope Creek, in-stream concentrations are expected to be due to naturally occurring selenium in the vicinity of the stream.

Because selenium concentrations would be expected to be higher during low flow conditions when groundwater dominates the flow regime, a well-rounded sampling program reflecting a broad range of flow conditions would be needed to properly characterize selenium concentrations in Antelope Creek. It should be noted that aquatic life criteria for selenium are more stringent than those for agricultural use and can be difficult to meet when natural sources of selenium are present. An alternative may be development of a site-specific standard based on natural conditions.

Conductivity and Chloride

NDEQ conductivity standards are in place for protection of agricultural water supply, with an upper limit of 2,000 umhos/cm between April 1 and September 30. NDEQ standards for chloride are 860 mg/L for single sample maximum or a four-day average concentration of 230 mg/L, with certain site-specific criteria allowed.

In the Antelope Creek TMDL, NDEQ notes that Antelope Creek has been characterized as being "quite salty" and, with the groundwater infiltrating the stream, to have a total dissolved solids concentration of about 30,000 mg/L (NNRC 1973). NDEQ's analysis of the available data shows a statistically significant trend (95% confidence interval) of decreasing conductivity with increasing stream flow. Other streams in the area have similar characteristics and have been classified with the Agriculture Class B beneficial use. Based on this information, NDEQ suggests that excessive conductivity may be a function of the geology or other natural conditions. Rather than complete a TMDL, NDEQ planned to forward Antelope Creek data to the Water Quality Standards

Coordinator for review. Options available include identification of a natural condition and a "Category 4C" assessment, site-specific water quality criteria or a use attainability analysis. Review of the 2010 Integrated Report again shows the stream as being listed as impaired due to elevated conductivity, as well as chloride (NDEQ 2010).

Specific conductance is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids in the water. High specific conductance indicates high dissolved-solids concentration; dissolved solids can affect the suitability of water for domestic, industrial, and agricultural uses. Agriculture is adversely affected by high-specific-conductance water, primarily due to diminished crop yield or failure resulting from saline water. Additionally, livestock and wildlife may be adversely affected by high specific conductance levels in surface water used as a water source. Generally, specific conductance levels in excess of 9,000 μmhos/cm are considered poor for livestock watering.

High conductivity can result from a variety of natural and human sources. Groundwater contains minerals from the aquifer rock material and can have significantly higher specific conductance. Agriculture can also be the cause of increases in the specific conductance of local waters. When water is used for irrigation, part of the water evaporates or is consumed by plants, concentrating the original amount of dissolved solids in less water; thus, the dissolved-solids concentration and the specific conductance in the remaining water is increased. The remaining higher specific-conductance water reenters the river as irrigation-return flow.

4.5. Summary and Conclusions

In summary, NDEQ prepared the Antelope Creek TMDL following procedures used in the river basins throughout the state. Stream impairment and the TMDL are based on limited data due to the responsibility that NDEQ has for monitoring and development TMDLs statewide; inherently restricting the breadth of monitoring on any particular stream. Nonetheless, even with limited data, it is clear that Antelope Creek does not attain Nebraska stream standards for *E. coli*. Conversely, it appears that a TMDL load reduction for ammonia is not needed. TMDLs are not believed to be effective approaches for facilitating reduction in selenium, chloride, and conductivity due to natural conditions. Due to limited data, it remains unclear whether a copper TMDL is warranted. Given that NDEQ considers the Antelope Creek a "phased TMDL", meaning that it can and should be revised based on the results of additional monitoring, it may be beneficial for the City to suggest revision of the TMDL once data have been synthesized and evaluated from the expanded monitoring program. The primary purpose of revising the TMDL would be to better delineate the City's responsibility under its waste load allocation (in relation to its MS4 permit) as opposed to natural sources of bacteria that should be included in a load allocation. Other conclusions relative to each constituent of concern include:

Picture 11: Groundwater boils can be found just past the Vine Street Bridge downstream to Salt Creek

- *E. coli:* While it may be possible to implement BMPs to reduce *E. coli* loading to Antelope Creek, it is highly unlikely that the water quality will meet numeric limits for *E. coli* bacteria during all months of the year due to natural contributions of *E. coli* to the stream. In addition to implementing BMPs, it may be beneficial for the City to explore how frequently *E. coli* standards are exceeded in similar streams that have minimal human or agriculture impacts, in order to develop a better sense of what is potentially attainable for Antelope Creek. Although the frequency of *E. coli* standard exceedances in an urban area would be expected to be greater than in a natural area, it would not be realistic to expect urban areas to be "cleaner than" natural areas. In Southern California, such "reference stream" data has been used to shape expectations for bacteria TMDLs.
- Ammonia: Review of existing data for ammonia suggests that a TMDL for ammonia is not needed since additional monitoring data conducted by NDEQ show no ammonia concentrations exceeding the stream standard.
- Copper: Due to the limited data set, it remains unclear whether copper is a pollutant of concern for Antelope Creek. Collection of additional samples would help to determine whether a TMDL for copper is needed.

- Selenium, Conductivity and Chloride: Uncertainty regarding appropriateness of existing designated stream uses and attainability of standards for selenium, conductivity and chloride remain; however, general consensus is that natural sources cause elevated levels of these constituents. As a result, changes of designated uses and/or site specific standards may be more appropriate approaches to resolve impairment listings for these constituents, as opposed to developing TMDLs for these constituents.

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