Estimating Predevelopment Hydrology for Urbanized Areas in New Mexico

Prepared for

U.S. Environmental Protection Agency

Office of Wastewater Management

Water Permits Division

Municipal Branch

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1 Introduction

Tetra Tech has been contracted by the USEPA to determine representative predevelopment hydrological conditions in urbanized areas in New Mexico. Managing stormwater to predevelopment hydrological conditions for newly developed and redeveloped sites is a goal of the existing Middle Rio Grande (MRG) Watershed Based Municipal Separate Storm Sewer System (MS4) Permit and the proposed Phase II MS4 General Permit to improve water quality. The MRG Watershed Based MS4 Permit offers discharge authorization to regulated Phase I and Phase II MS4s within the boundaries of the Bureau of the Census-designated 2000 and 2010 Albuquerque Urbanized Areas (UAs) and any other MS4s in the watershed designated by the USEPA as needing an MS4 permit. The proposed Phase II general permit offers discharge authorization to the rest of the regulated MS4s within the boundaries of the Bureau of the Census-designated 2000 and 2010 UAs in New Mexico (Farmington, Santa Fe, Los Lunas, Las Cruces and El Paso). The MRG Watershed Based MS4 permit incorporates a stormwater quality design standard that manages on-site the 90th percentile storm event discharge volume associated with new development sites and the 80th percentile storm event discharge volume associated with redevelopment sites. The Phase II MS4 General Permit is proposing similar stormwater quality design standards (post construction standards) which uses a percentile storm event approach as a surrogate for mimicking predevelopment hydrology. In June 2014, USEPA received a petition to designate Los Alamos County, NM (mainly aimed at Los Alamos and Los Alamos National Laboratory (LANL)) as regulated MS4s. Since it is not located in a Census UA, the city/county and the LANL federal facility are not currently regulated MS4s and would have to be designated before a permit for municipal stormwater would be required. This study includes a similar predevelopment hydrology analysis of the Los Alamos and Whiterock urban clusters.

This study builds on a predevelopment hydrology study in the Middle Rio Grande watershed (Kosco, et. al., 2014) and uses an updated and more detailed methodology to estimate predevelopment hydrology for all urbanized areas in New Mexico.

The objectives of this study are as follows,

1) Determine representative predevelopment hydrological conditions for urbanized areas in New Mexico considering appropriate parameters including rainfall, soil types, topography, land cover and evapotranspiration.
2) Determine the percentile rainfall relationships for each area of interest.
3) Validate if the capture of the 90th percentile storm event is an acceptable standard based upon the analyses above.

2 Predevelopment Hydrological Conditions

The Soil and Water Assessment Tool (SWAT) was used to simulate runoff behavior under pre-development landuse conditions for the Albuquerque, Farmington, Santa Fe, Los Lunas, Las Cruces, and El Pasco urbanized areas, and the Los Alamos and Whiterock urban clusters. SWAT is a basin-scale, continuous model that operates on a daily time-step. It is designed to predict the impact of management on water, sediment and agricultural chemical yields in watersheds and is capable of predicting water quantity, water quality and sediment yields from large, complex watersheds with variable land uses, elevations and soils. The model is physically based, computationally efficient and capable of continuous simulation over long periods (Neitsch *et al.*, 2011).

SWAT uses a curve number approach to estimate runoff. An initial curve number is assigned to landuses in the model based upon hydrologic soil group (HSG) of the underlying soil and slope of the land. Daily curve number in the model varies based upon antecedent soil moisture; that is, runoff is affected by the soil moisture before a precipitation event. The curve numbers suggested for different types under different hydrologic conditions are essentially average curve numbers for average soil moisture conditions (CN_{II}). Curve numbers may vary from CN_I (dry) to CN_{III} (wet). Consideration for antecedent moisture can thus lower or increase the value of curve number on a given day, with probable impacts on total runoff volume. It should be noted that this approach utilizes the same basic methodologies as the previously noted predevelopment hydrology study (Kosco, et. al., 2014) for the Middle Rio Grande watershed with enhancements to consider antecedent moisture conditions

In a SWAT model, a watershed or study area is divided into several subbasins (urban areas/clusters in this case), which are then further subdivided into hydrologic response units (HRUs) on the basis of unique combinations of land use, soil and slope class. An HRU is the smallest physical entity for which all hydrologic processes are simulated. The hydrologic output at the sub-watershed level is generated by aggregating the output at the HRU level. HRUs are generated for the model by overlaying spatial datasets (namely, subbasins, landuse, soil and slope) using the ArcGIS interface of the SWAT model (ArcSWAT).

The following sections discuss the data sources used for the development of the SWAT model and a brief discussion of the hydrologic simulation.

2.1 URBAN AREAS/CLUSTERS

A total of 7 urbanized areas (UA)/urban clusters (UC) were assessed in this analysis.

- Farmington UA
- Los Alamos and Whiterock UC
- Santa Fe UA
- Albuquerque UA
- Los Lunas UA
- Las Cruces UA
- El Paso UA

Each of these urbanized areas/urban clusters were modeled as a separate *subbasin* in the SWAT model. The pre-development hydrology analysis was conducted for each of these urbanized areas/urban clusters. Maps of the physical bounds of these urbanized areas/urban clusters are depicted in Appendix A. The El

Paso UA includes a significant portion that is in the state of Texas. This area is included in the maps, but was not included in the analysis.

2.2 ELEVATION AND SLOPE

A 30m resolution digital elevation model (DEM) was used to calculate elevation and slope associated with the subbasins and HRUs.

Slope is an important factor used in the calculation of curve numbers. The curve numbers suggested by SCS are appropriate for a 5% slope. As a result, curve numbers in the SWAT model were adjusted for slope using the equation developed by Williams (1995). Maps of elevation and slope associated with the urbanized areas/urban clusters are depicted in Appendix B.

2.3 LANDUSE

The use of a landuse dataset that represents pre-development conditions with relative accuracy is important to address the general objective of this project. The environmental site potential (ESP) dataset was used for the representation of pre-development landuse conditions in the study area.

The ESP dataset is an abstract concept which represents the vegetation that could be supported at a given site based on a biophysical environment. The landuse/landcover categories represent the natural plant communities that would become established at late or climax stages of successional development in the absence of disturbance. They reflect the current climate and physical environment, as well as the competitive potential of native plant species. Maps of ESP expressions in the urbanized areas/urban clusters are depicted in Appendix C.

2.4 SOIL

The USDA's detailed Soil Survey Geographic Database (SSURGO) soil data were generally used in the SWAT model. The less detailed State Soils Geographic Database (STATSGO), which classifies areas according to dominant soil components, was used for a small part of the Los Alamos National Laboratory (LANL) that lacked SSURGO data.

The following properties required for each HRU were extracted from the soil databases stated above.

- Number of horizons
- Hydrologic soil group
- Maximum rooting depth
- Anion exchange capacity
- Soil cracking potential

For each soil horizon, the following properties are required and were extracted from the SSURGO or STATSGO databases.

- Depth of horizon
- Bulk density
- Available water capacity
- Hydraulic conductivity
- Percent organic carbon
- Percent sand, silt and clay
- Percent rock
- Albedo

- USLE erosivity factor
- Electrical conductivity

Hydrologic soil group (HSG) is of one of the primary properties used in the determination of curve numbers. A soil may be placed under one of the four groups: A, B, C and D, or three dual classes, A/D, B/D and C/D. The definitions of these classes are,

A: Sand, loamy sand or sandy loam types of soils. Low runoff potential and high infiltration rates even when thoroughly wetted. Consist chiefly of deep, well to excessively drained sands or gravels with a high rate of water transmission.

B: Silt loam or loam. Moderate infiltration rates when thoroughly wetted. Consist chiefly or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

C: Soils are sandy clay loam. Low infiltration rates when thoroughly wetted. Consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.

D: Soils are clay loam, silty clay loam, sandy clay, silty clay or clay. Group D has the highest runoff potential. Low infiltration rates when thoroughly wetted. Consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface and shallow soils over nearly impervious material.

Dual HSGs are assigned to certain wet soils with adequate drainage. The first letter (A, B, C) applies to the drained condition and the second (D) applies to the un-drained. Maps of the HSGs of soils in the urbanized areas/urban clusters are depicted in Appendix D.

2.5 METEOROLOGICAL DATA

SWAT requires daily precipitation, maximum and minimum air temperature, solar radiation, wind speed and relative humidity for continuous simulation. The minimum required meteorological time series for SWAT simulations are daily precipitation, and maximum and minimum air temperature. Potential evapotranspiration (PET) is also required for simulation, but the model estimates it directly using one of several options. For this model, the Penmann-Monteith energy balance method was adopted for the estimation of PET using a statistical weather generator for inputs other than temperature and precipitation.

NCDC Summary of the Day meteorological data available from EPA-BASINS were used for the development of precipitation and temperature forcing files for the model. EPA-BASINS data are filled for gaps and disaggregated to an hourly time-step. The EPA-BASINS system does not have data for the recent years. From 2010 to 2013, precipitation and temperature data were directly downloaded from NCDC and patched using MetADAPT (an MS Excel based weather data processing tool) to fill data gaps. One weather station was assigned to each urban area/cluster. The SWAT model was setup for a time-frame of 34 years from 1/1/1980 to 12/31/2013. Table 1 lists the NCDC stations used for the meteorological forcing.

Table 1. Meteorological stations used in the analysis

NCDC ID	NAME	LAT	LONG	ELEV (m)
290234	Albuquerque International Airport	35.0356	-106.622	1618.49
293142	Farmington Agricultural Science Center	36.6897	-108.309	1714.5
295084	Los Alamos	35.8644	-106.321	2262.84
295150	Los Lunas 3 SSW	34.7675	-106.761	1475.23
298085	Santa Fe 2	35.6194	-105.975	2059.23
298535	State University (Las Cruces)	32.2822	-106.76	1182.93
412797	El Paso Airport	31.8111	-106.376	1194.21

2.6 PRE-DEVELOPMENT HYDROLOGY SIMULATION

The SWAT model was run from 1/1/1980 to 12/31/2013. Simulation results from the most recent 30-years (1/1/1984 to 12/31/2013) were used for the pre-development hydrology analysis. The first four years were used for model *spin-up* only.

A traditional SWAT modeling exercise consists of calibration and validation for hydrology. Calibration and validation generally consist of comparing the simulated flow to observed flow until they are in close agreement with each other. This exercise results in an estimate of model parameter values that represent the hydrological behavior of the study area. Given the general lack of observed flow data, a *soft* calibration strategy was pursued wherein the objective was to have a reasonable representation of the hydrologic cycle and biomass simulation under pre-development landuse conditions.

3 Percentile Rainfall Analysis

Understanding local weather patterns is essential to accurately reflect expected volume, intensity, and duration of expected storm events with high spatial variability in meteorology. Given the variable but primarily arid climate of New Mexico where rainfall is generally sparse but ranges due to topographical variability among other factors, this understanding becomes even more important. A percentile rainfall analysis utilizes long-term meterological records to evaluate precipitation event distributions in terms of percentiles. Percentile rainfall analysis is commonly used as the basis for stormwater retention standards.

3.1 Calculating Percentile Rainfall Events

Chapter 4 of the Center for Watershed Protection's (CWP) guidance document for building an effective post-construction stormwater management program (Hirshman and Kosco 2008) recommends using daily time step data as an approximation for estimating 24-hour rainfall distributions. Figure 1, taken from the CWP guidance, describes the process of developing a rainfall frequency spectrum which is used to calculate percentile storms for an area. In general, a weather station with at least 30 years of daily rainfall records is used. Small storms of less than 0.1 inch are edited out and the entire rainfall record is sorted from largest to smallest and numbered. A percentile is then assigned based on the total number of rainfall records (for example, the 10th largest storm out of a total record of 500 days of recorded rainfall greater than 0.1 inch would be in the 98th percentile → (500-10)/500 x 100% = 98%).

Why are small storms not included in calculating the percentile rainfall event?

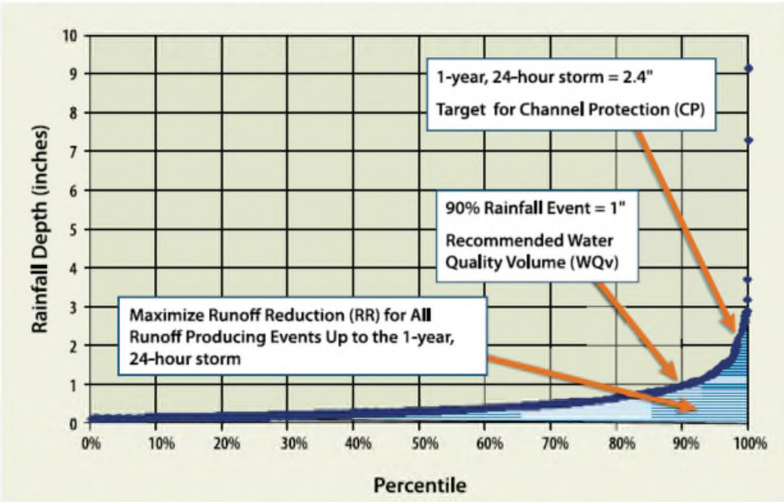
The rainfall from minor storms may be entirely stored in surface depressions and eventually lost to evaporation or infiltration. As a result, no runoff is produced.

Schueler (1987) developed a Simple Method for estimating storm pollutant load export delivered from urban development sites. From the analysis of National Urban Runoff Program (NURP) data and storm events recorded at National Airport, Schueler found that the runoff coefficient needed to be corrected to eliminate the portion of annual rainfall which does not produce any direct runoff. The analysis found that about 10% of the annual rainfall volume is so slight that no appreciable runoff is produced.

A Rainfall Frequency Spectrum (RFS) is a tool that stormwater managers should use to analyze and develop local stormwater management criteria and to provide the technical foundation for the criteria.

Over the course of a year, many precipitation events occur within a community. Most events are quite small, but a few can create several inches of rainfall. An RFS illustrates this variation by describing how often, on average, various precipitation events (adjusted for snowfall) occur during a normal year.

The graph below provides an example of a typical rainfall frequency spectrum and shows the percentage of rainfall events that are equal to or less than an indicated rainfall depth. As shown, the majority of storm events are relatively small, but there is a sharp upward inflection point that occurs at about 1 inch of rainfall (90% rainfall event). The 90% rainfall depth is the recommended standard for the Water Quality Volume (see **Table 4.7**).



Rainfall Frequency Spectrum for Minneapolis-St. Paul, MN (1971–2000) with several noteworthy rainfall events identified (adapted from MSSC, 2005).

Guidance on creating an RFS is provided below. If a community is large in area or has considerable variation in elevation or aspect, the RFS analysis should be conducted at multiple stations.

1. Obtain a long-term rainfall record from an adjacent weather station (daily precipitation is fine, but try to obtain at least 30 years of daily record). NOAA has several Web sites with long-term rainfall records (see *http://www.nesdis.noaa.gov*). Local airports, universities, water treatment plants, or other facilities might also maintain rainfall records.
2. Edit out small rainfall events than are 0.1 inch or less, as well as snowfall events that do not immediately melt.
3. Using a spreadsheet or simple statistical package, analyze the rainfall time series and develop a frequency distribution that can be used to determine the percentage of rainfall events less than or equal to a given numerical value (e.g., 0.2, 0.5, 1.0, 1.5 inches).
4. Construct a curve showing rainfall depth versus frequency, and create a table showing rainfall depth values for 50%, 75% 90%, 95% and 99% frequencies.
5. Use the data to define the Water Quality storm event (90th percentile annual storm rainfall depth). This is the rainfall depth that should be treated through a combination of Runoff Reduction (**Table 4.6**) and Water Quality Volume treatment (**Table 4.7**).
6. The data can also be used develop criteria for Channel Protection (**Table 4.8**). The 1-year storm (approximated in some areas by the 99% rainfall depth) is a good standard for analyzing downstream channel stability.
7. Other regional and national rainfall analysis such as TP-40 (NOAA) or USGS should be used for rainfall depths or intensity greater than 1 year in return frequency (e.g., 2-, 5-, 10-, 25-, 50-, or 100-year design storm recurrence intervals).

Figure 1. Guidance on creating a rainfall frequency spectrum (Hirshman and Kosco 2008).

3.2 Rainfall Analysis for New Mexico Urban Areas

A percentile rainfall analysis using the methods discussed above was conducted on continuous fixed 24-hour interval rainfall data for each of the weather stations discussed in Section 2.5. Daily rainfall events less than or equal 0.1 inches were ignored. The 90th and 95th percentile event values for each station are reported in Table 2, and Figure 2 shows the complete percentile rainfall relationship.

Table 2. 80th, 90th and 95th percentile rainfall events (inches)

NCDC ID	NAME	80th percentile	90th percentile	95th percentile
290234	Albuquerque International Airport	0.48	0.65	0.84
293142	Farmington Agricultural Science Center	0.40	0.53	0.70
295084	Los Alamos	0.53	0.69	0.93
295150	Los Lunas 3 SSW	0.48	0.71	0.90
298085	Santa Fe 2	0.50	0.68	0.87
298535	State University (Las Cruces)	0.55	0.78	0.95
412797	El Paso Airport	0.54	0.82	1.08

NOTES:

- The previous predevelopment runoff study (Kosco, et. al., 2014) used data from the Albuquerque International Airport for the period 1950-2012. Because rainfall data for the other stations studied in this report did not extend back to 1950, this report used the most recent 30 year period of record (1983-2013) for all stations which resulted in a slightly higher 90th percentile event for Albuquerque.
- In terms of implementing the post construction standards in the Albuquerque UA, data should be used from the previous predevelopment runoff study (Kosco, et. al., 2014) or estimated through site specific pre-development hydrology and associated storm event discharge volume using the methodology specified in the 2014 USEPA Technical Report.

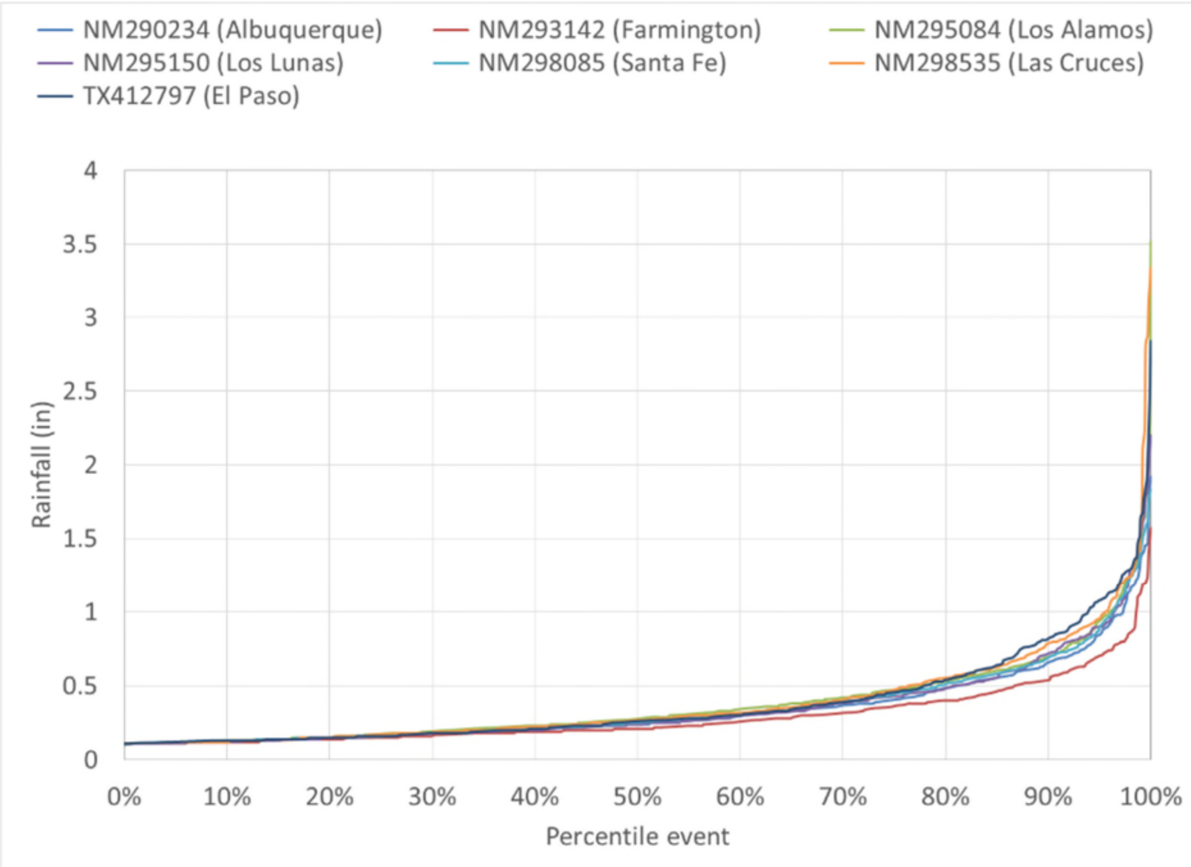


Figure 2. Percentile rainfall analysis

4 Results and Discussion

As stated in Section 2.6, a soft calibration approach was adopted to ensure that the hydrologic cycle and plant biomass were being simulated reasonably by the SWAT model. Table 3 shows the average annual water balance for each urbanized area over a 30 year period as simulated by the SWAT model.

Table 3. Average annual water balance for each urbanized area

Urbanized Area/Urban Cluster	Potential Evapotranspiration (in/yr)	Precipitation (in/yr)	Evapo-transpiration (in/yr)	Surface Runoff (in/yr)	Lateral Flow (in/yr)	Return Flow (in/yr)
Farmington UA	42.95	8.32	8.02	0.06	0.10	0.10
Los Alamos UC	39.77	18.70	16.00	1.74	0.53	0.37
Santa Fe UA	42.14	13.79	12.27	0.41	0.28	0.80
Albuquerque UA	46.31	9.35	9.10	0.04	0.08	0.05
Los Lunas UA	48.55	9.75	9.61	0.02	0.03	0.04
Las Cruces UA	53.58	9.63	9.31	0.05	0.13	0.13
El Paso UA	54.72	9.39	8.85	0.23	0.07	0.19

The above hydrologic behavior shows a very low surface runoff and high evapotranspiration, which is expected under pre-development conditions. The average annual simulated biomass (important for evapotranspiration) was also reasonable with most of the landuses producing more than 1 metric-ton/ha except for barren landuses.

A rainfall-runoff analysis was then conducted on each of the urbanized areas considered in this study. Figure 3 through Figure 9 below show the rainfall-runoff response as well as the 90th percentile rainfall event in each of the 7 urbanized areas/urban clusters. It is evident from the figures that with the exception of Los Alamos and Santa Fe, runoff generally does not begin until the 90th percentile event. For Los Alamos and Santa Fe, runoff begins well before the 90th percentile event is reached. It is important to note that both of these areas have a large percentage of high sloping areas which may be a contributing factor to higher runoff compare to the other urban areas. The figures also include the 0.6 inch 90th percentile event for Albuquerque as a comparison.

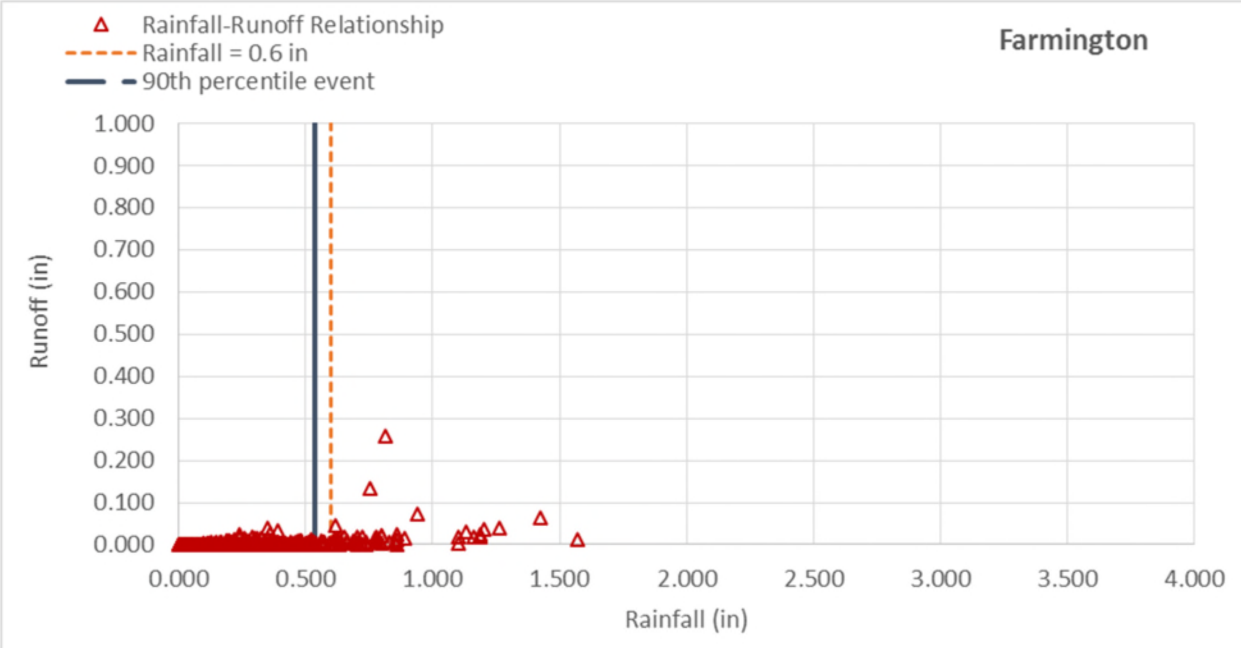


Figure 3. Rainfall-runoff response for Farmington

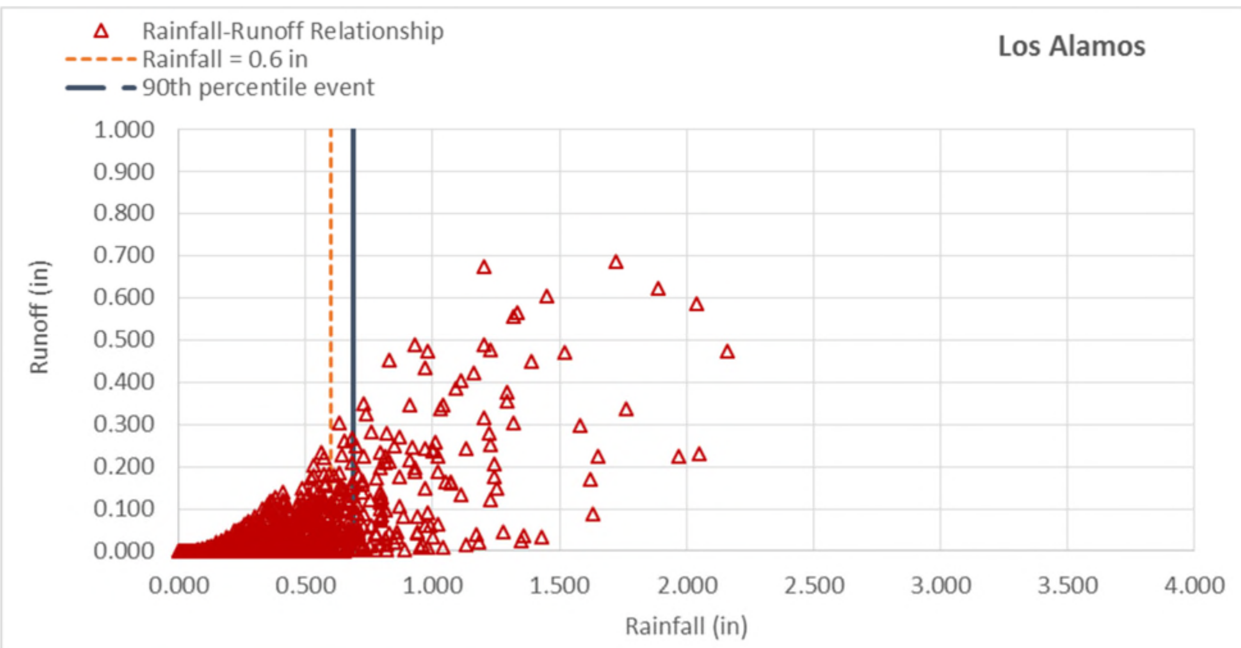


Figure 4. Rainfall-runoff response for Los Alamos

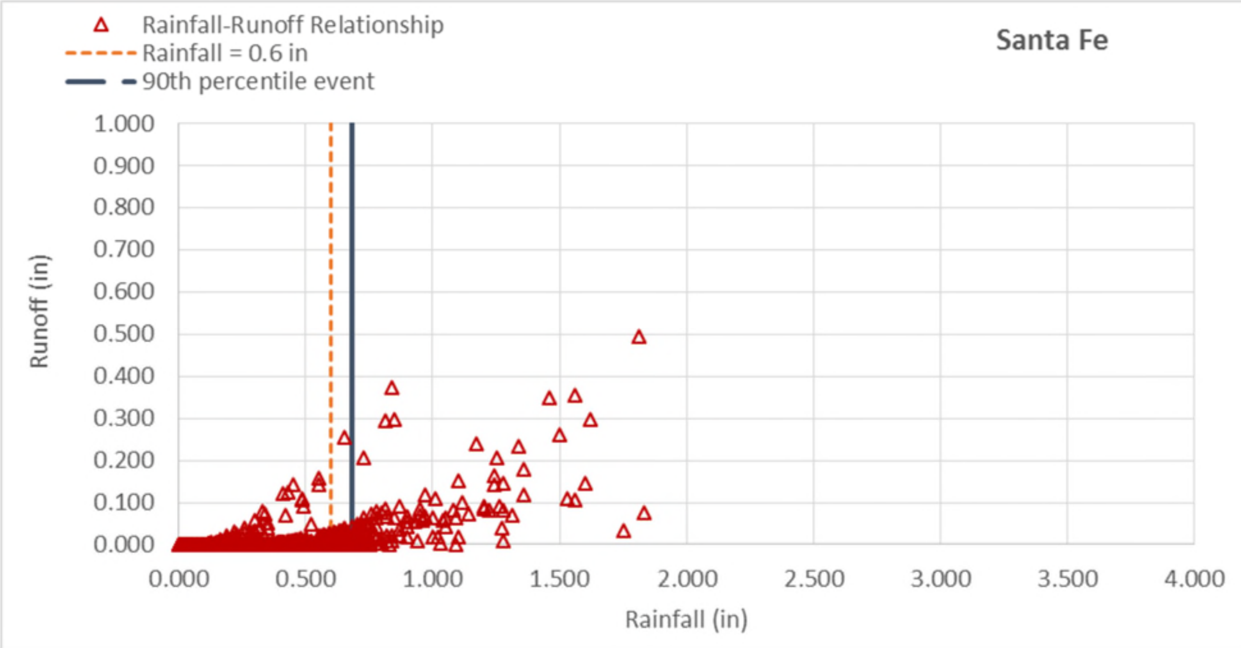


Figure 5. Rainfall-runoff response for Santa Fe

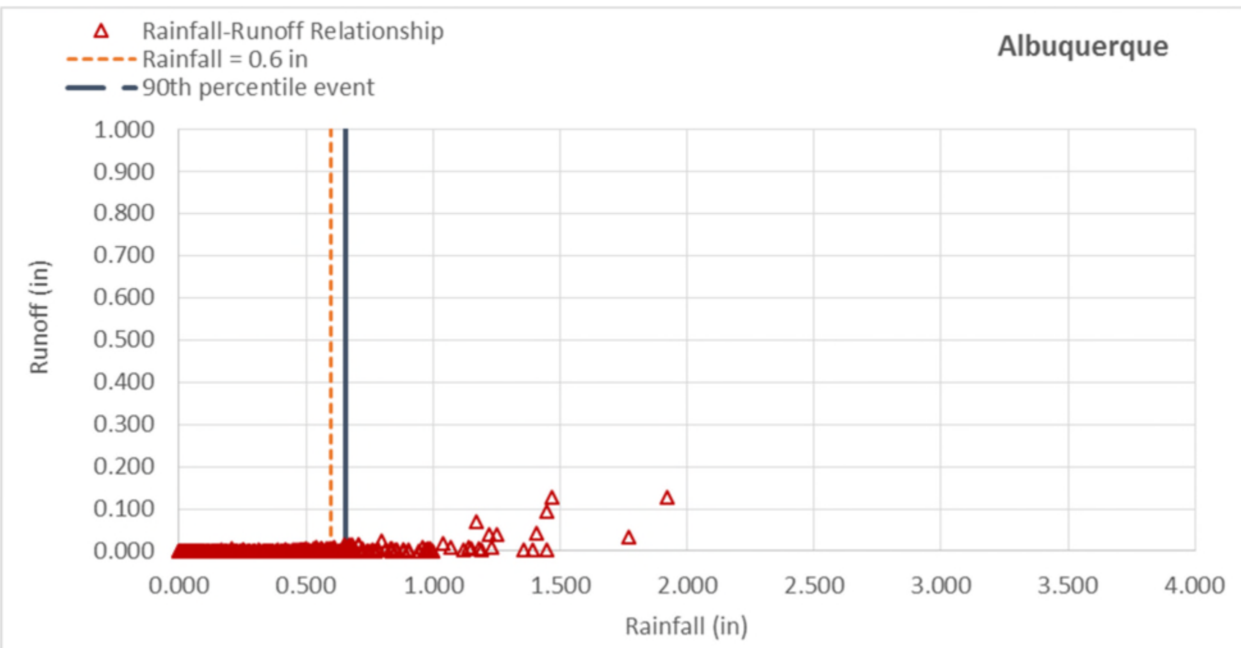


Figure 6. Rainfall-runoff response for Albuquerque

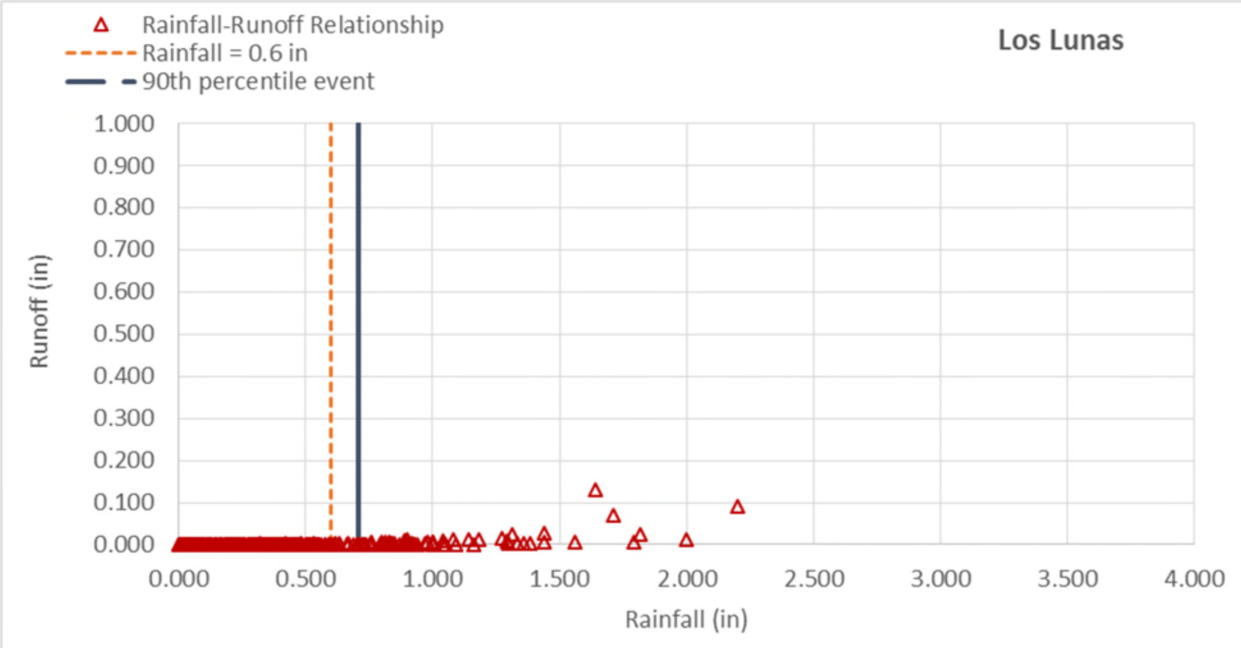


Figure 7. Rainfall-runoff response for Los Lunas

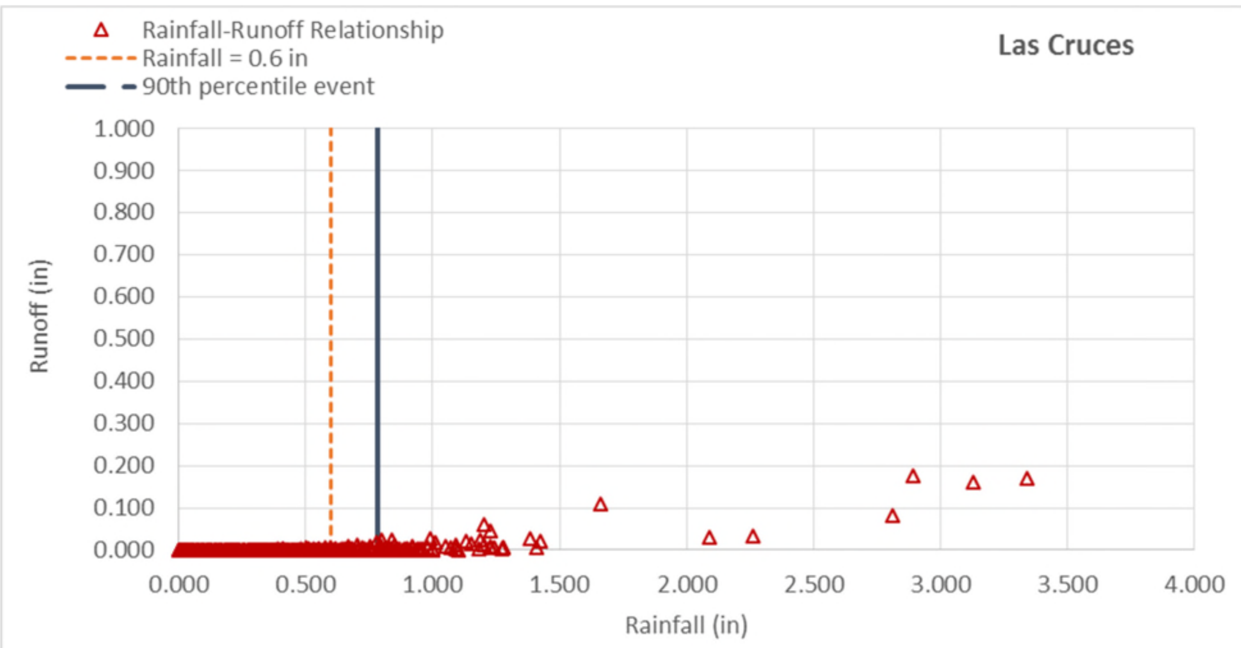


Figure 8. Rainfall-runoff response for Las Cruces

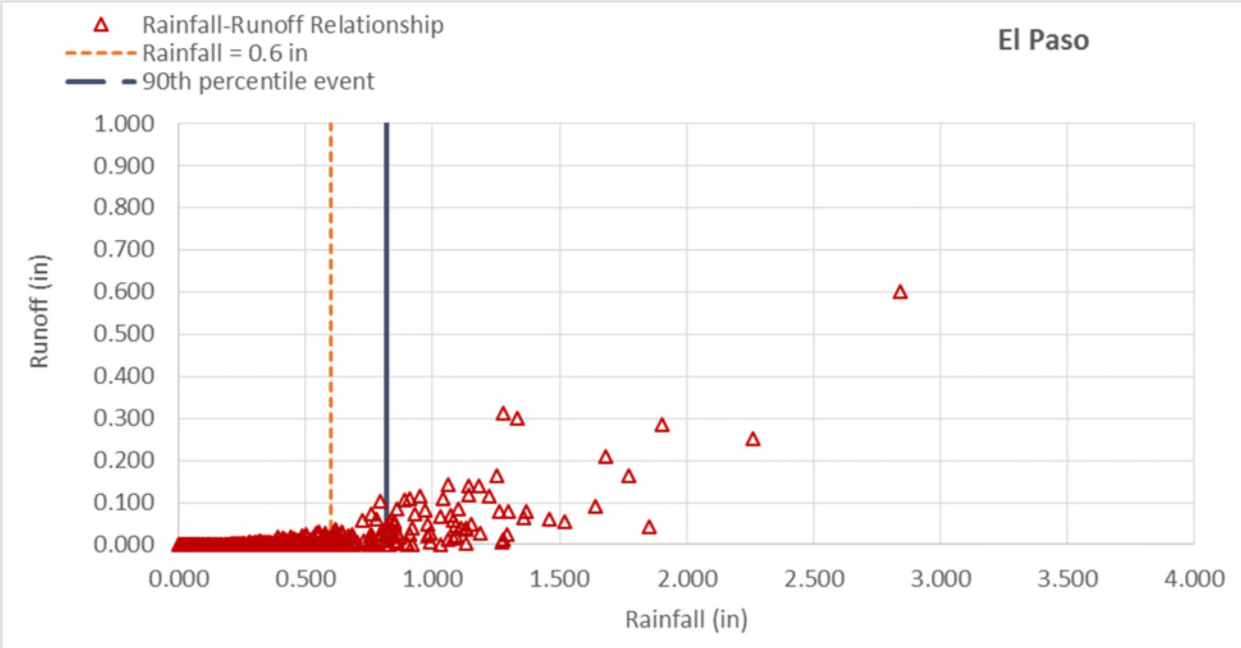


Figure 9. Rainfall-runoff response for El Paso

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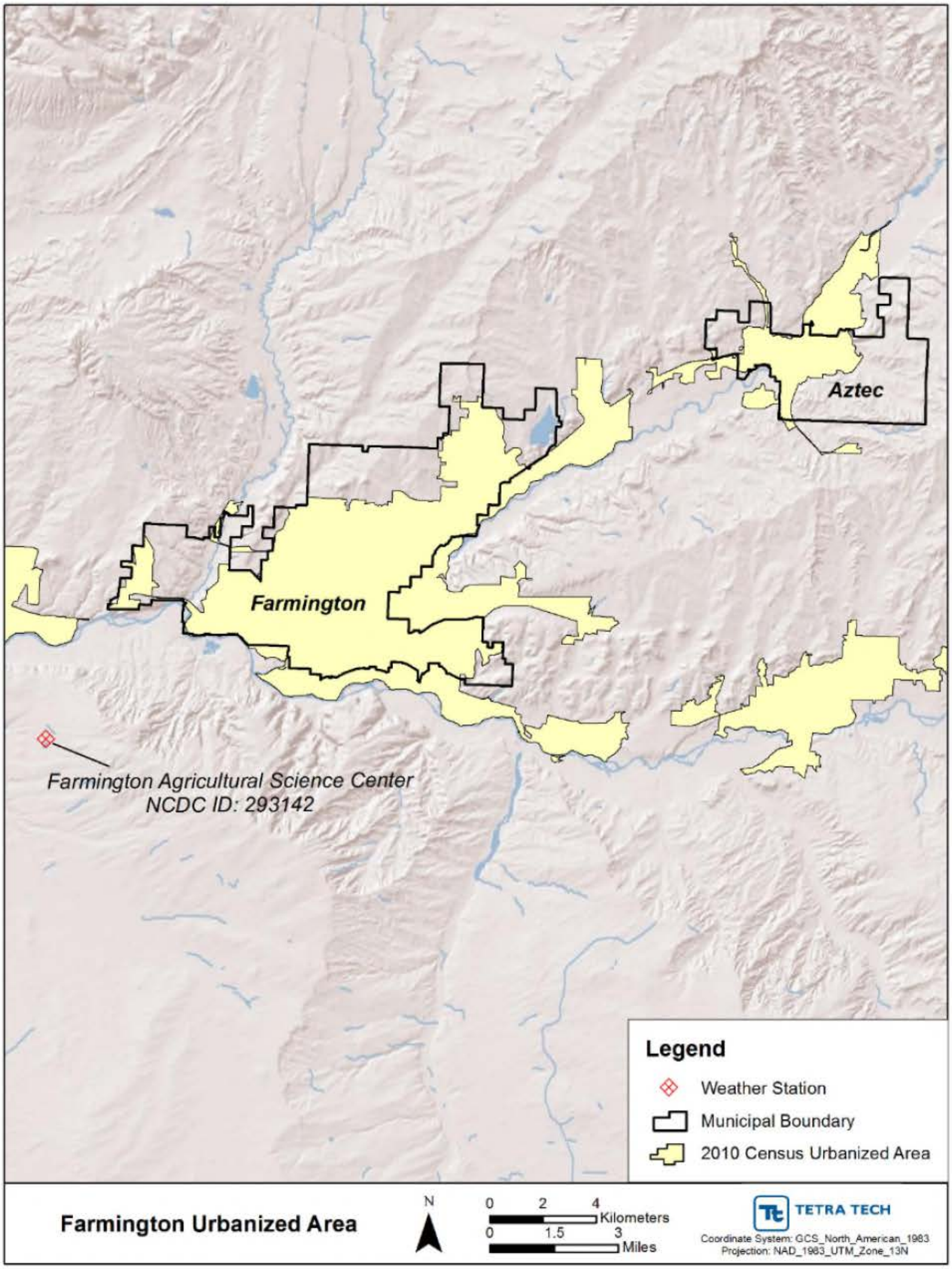
Appendix A Urbanized Areas/Urban Cluster Boundaries


Aztec
Farmington
Farmington Agricultural Science Center
NCDC ID: 293142
Legend
Weather Station
Municipal Boundary
2010 Census Urbanized Area
Farmington Urbanized Area
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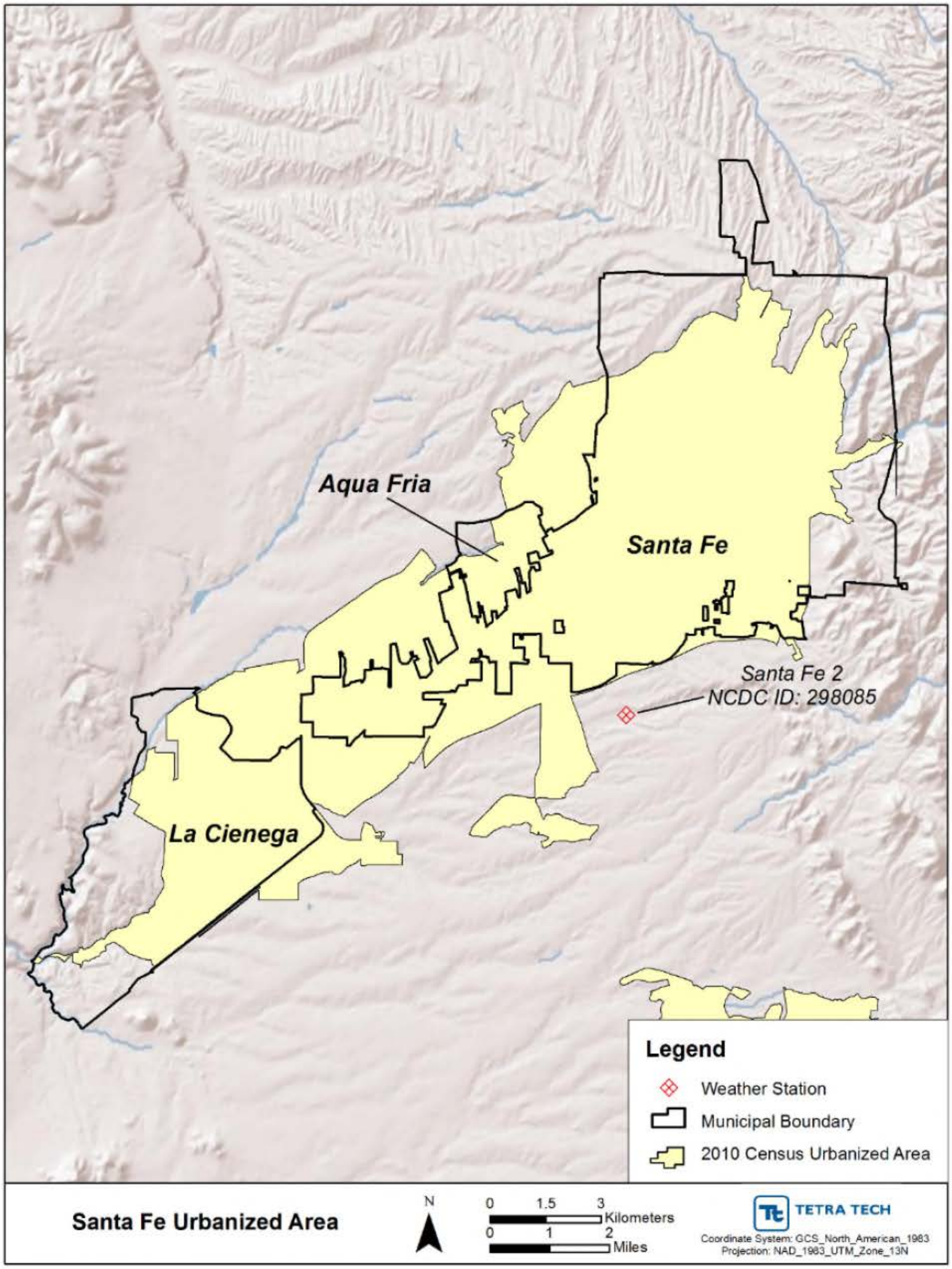

Aqua Fria
Santa Fe
Santa Fe 2
NCDC ID: 298085
La Cienega
Legend
Weather Station
Municipal Boundary
2010 Census Urbanized Area
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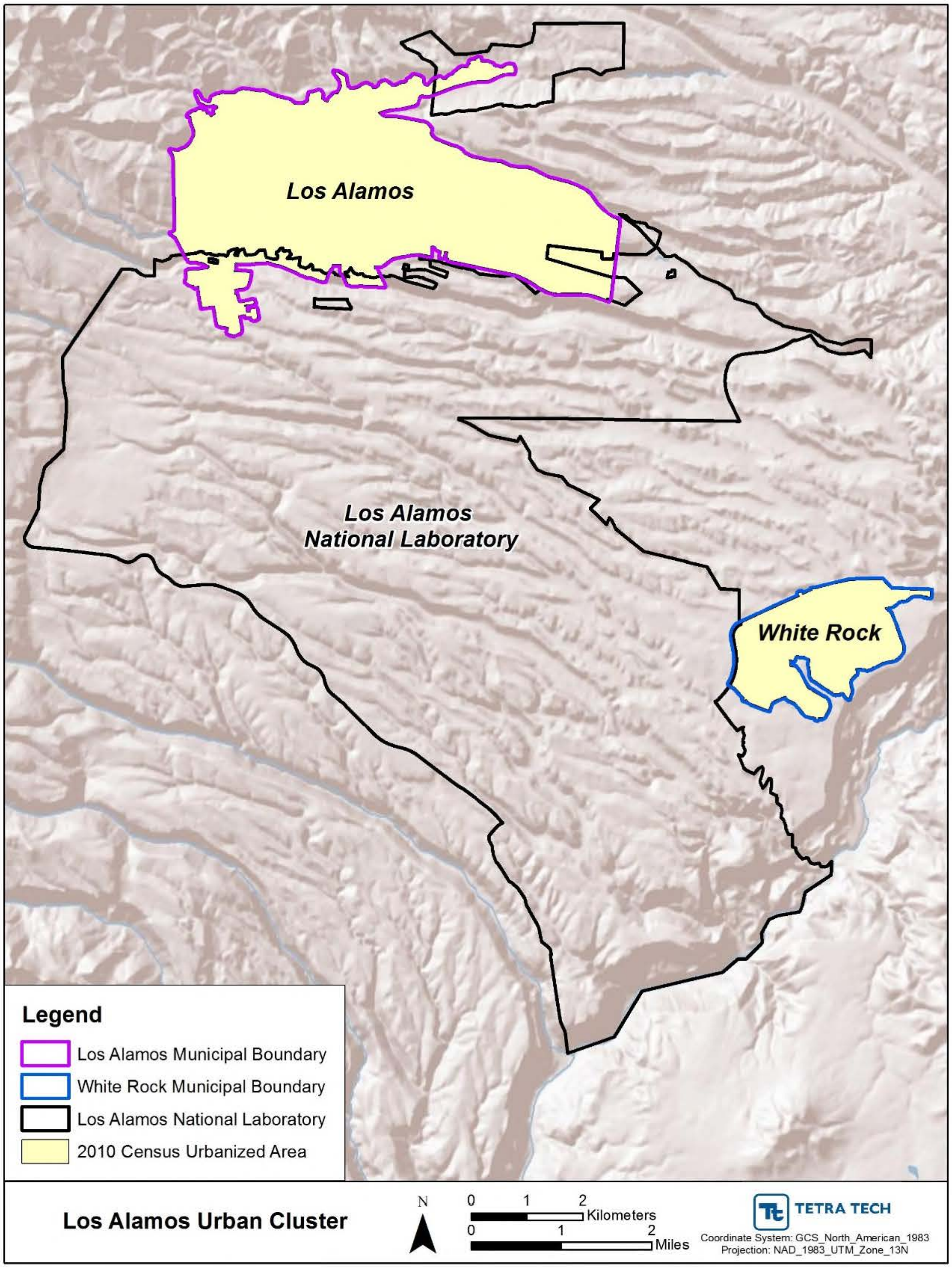
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Los Alamos National Laboratory
White Rock
Legend
Los Alamos Municipal Boundary
White Rock Municipal Boundary
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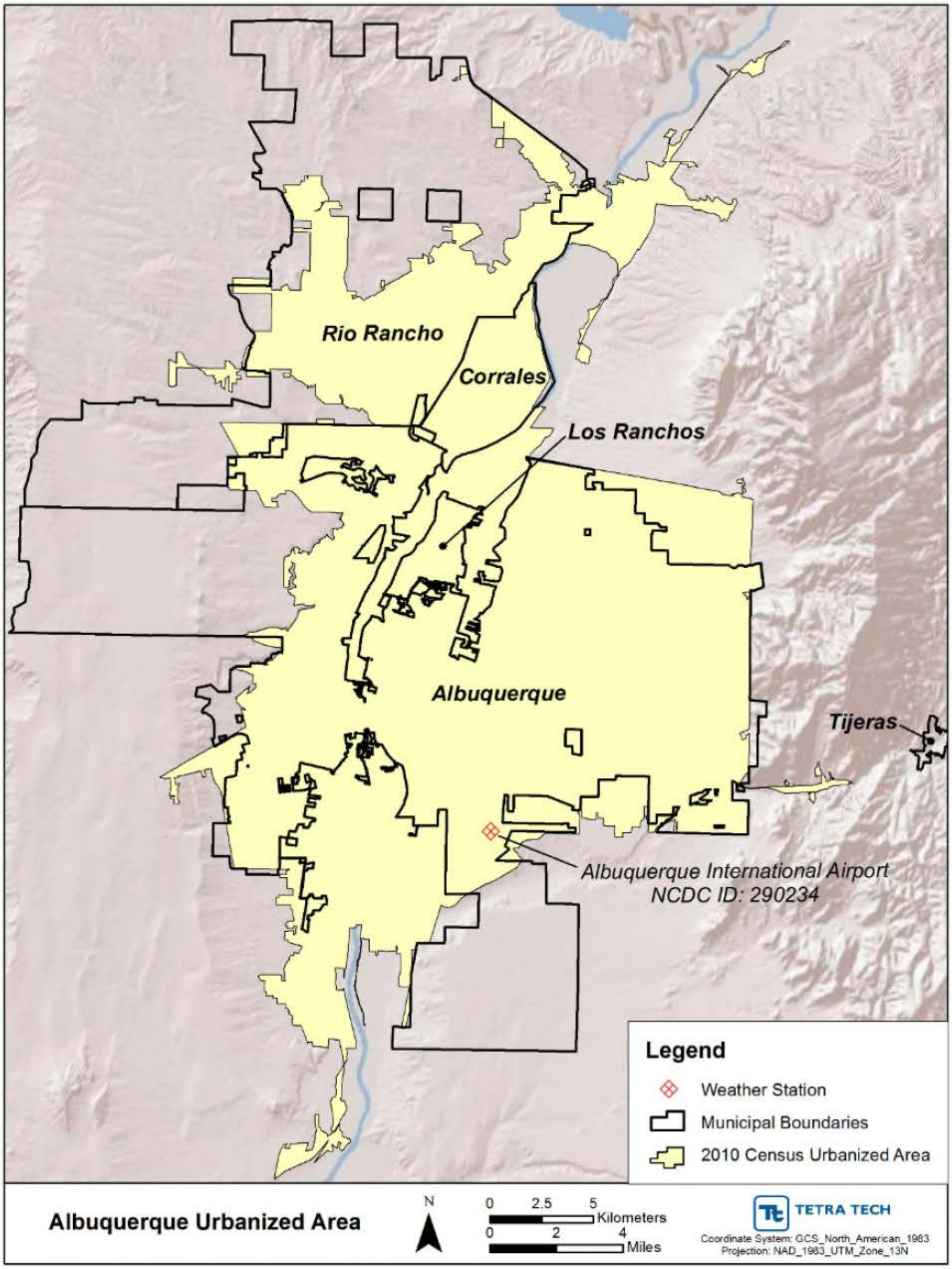
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Tijeras
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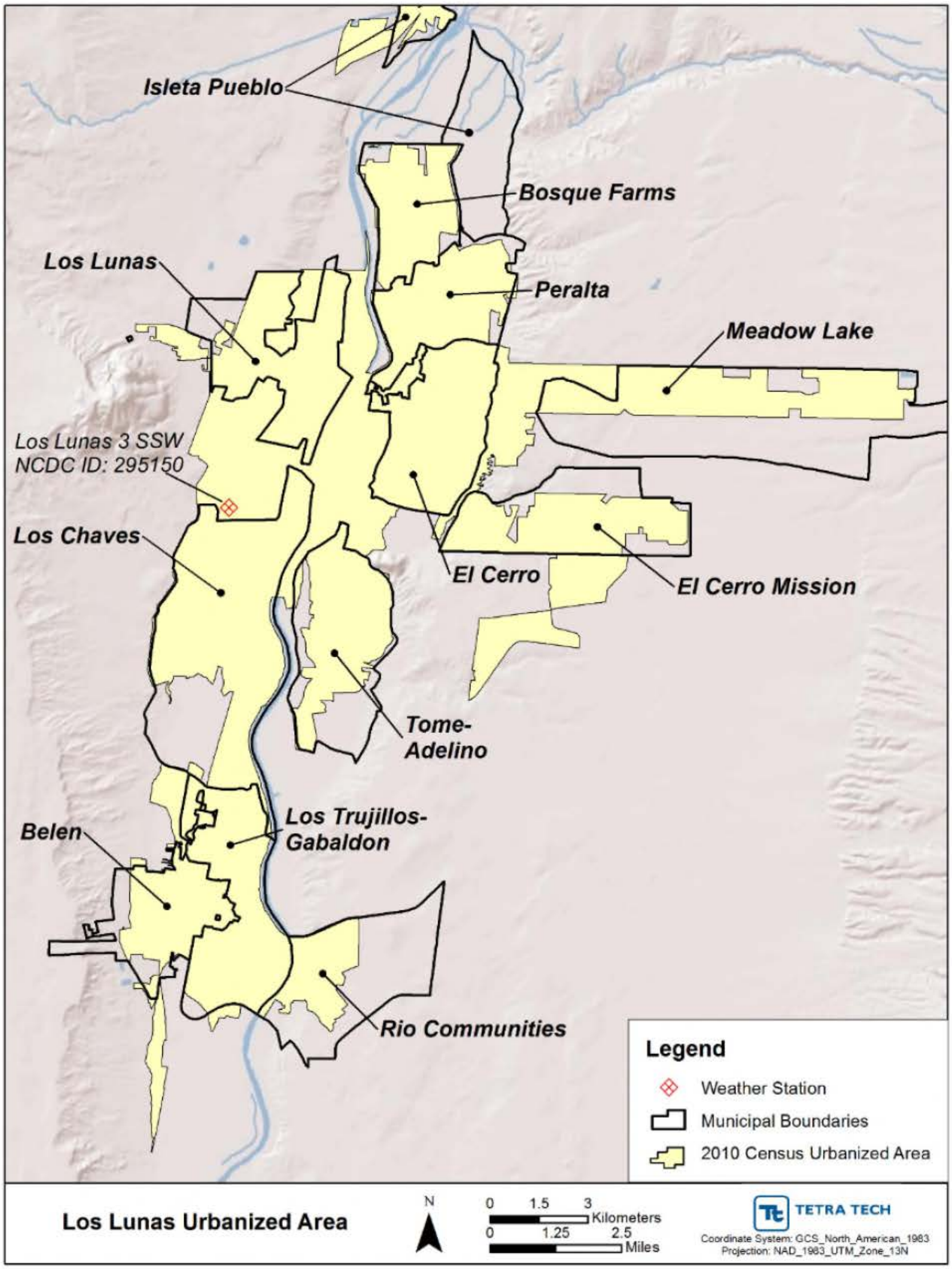
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Los Lunas
Peralta
Meadow Lake
Los Lunas 3 SSW
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Los Chaves
El Cerro
El Cerro Mission
Tome-
Adelino
Los Trujillos-
Gabaldon
Belen
Rio Communities
Legend
Weather Station
Municipal Boundaries
2010 Census Urbanized Area
Los Lunas Urbanized Area
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0 1.25 2.5 Miles
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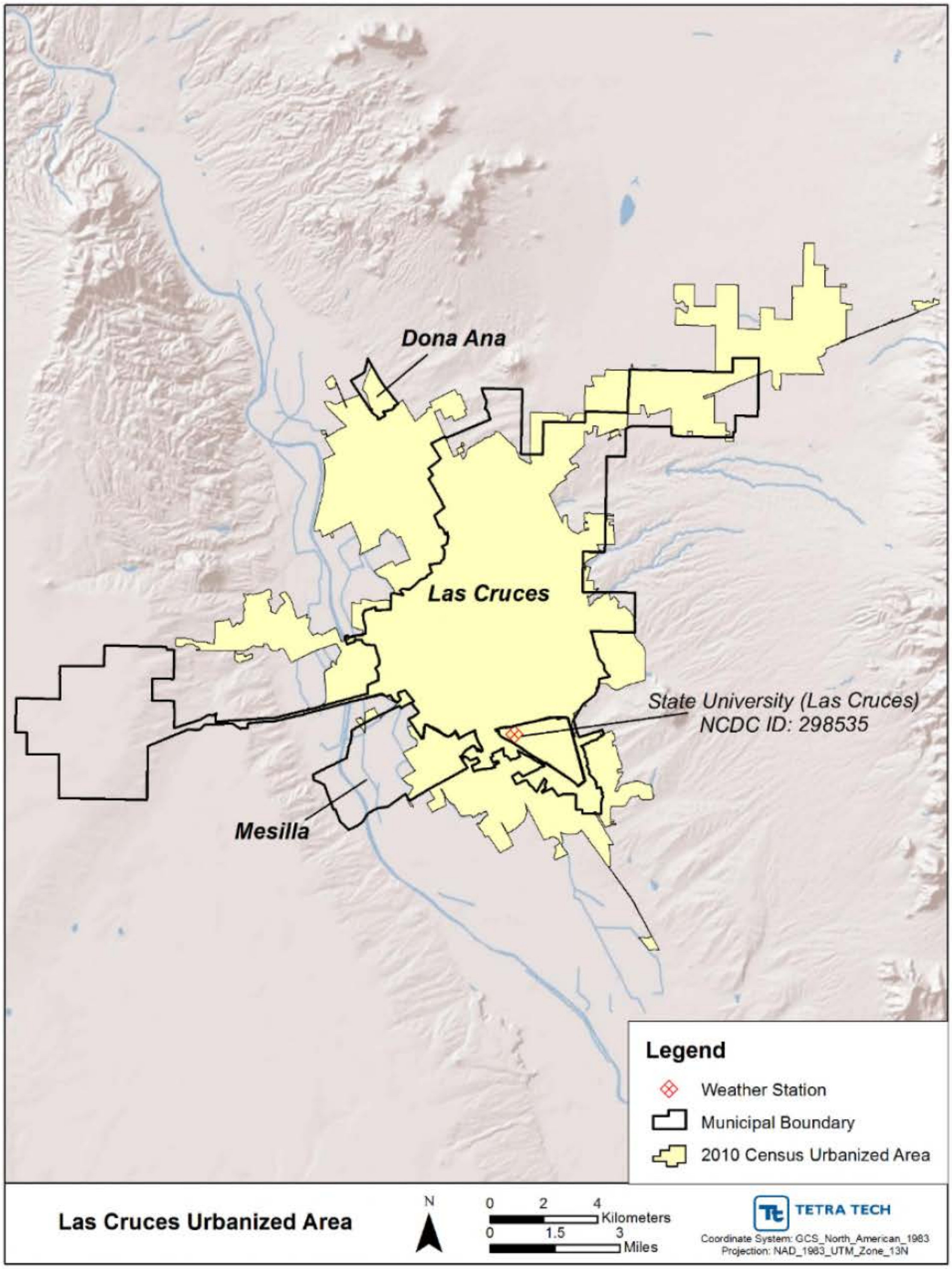
Dona Ana
Las Cruces
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Weather Station
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Las Cruces Urbanized Area
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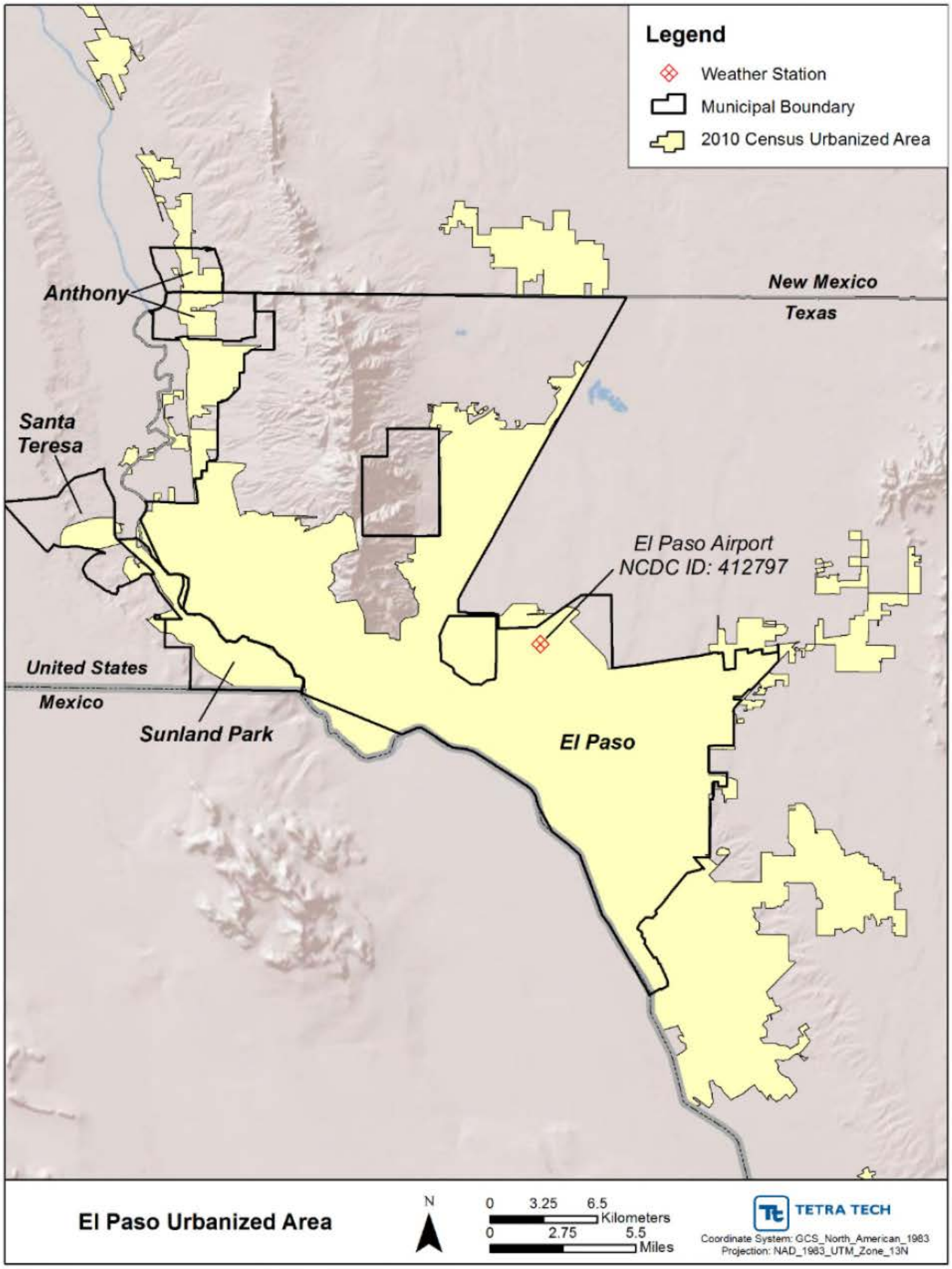
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Municipal Boundary
2010 Census Urbanized Area
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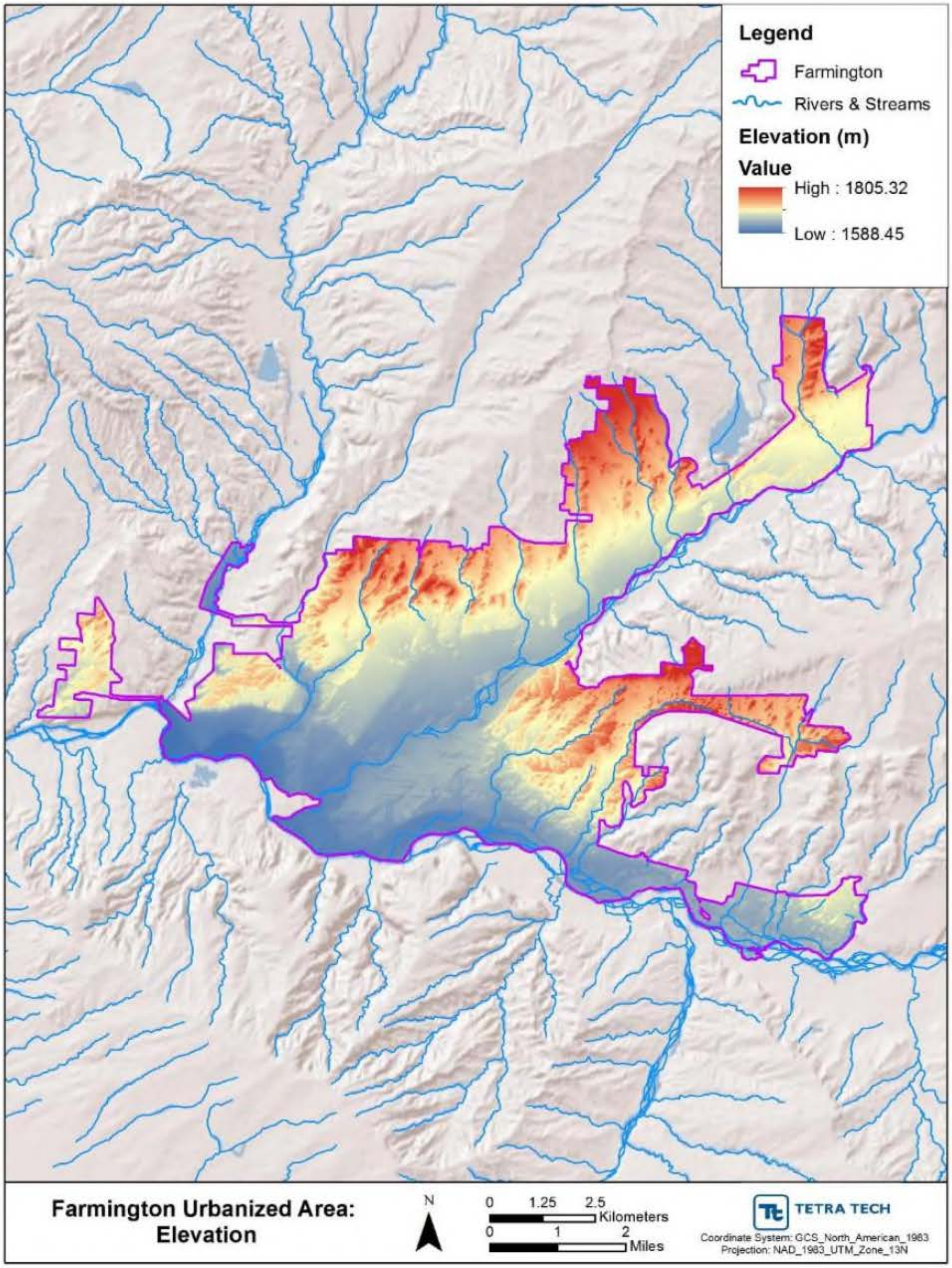
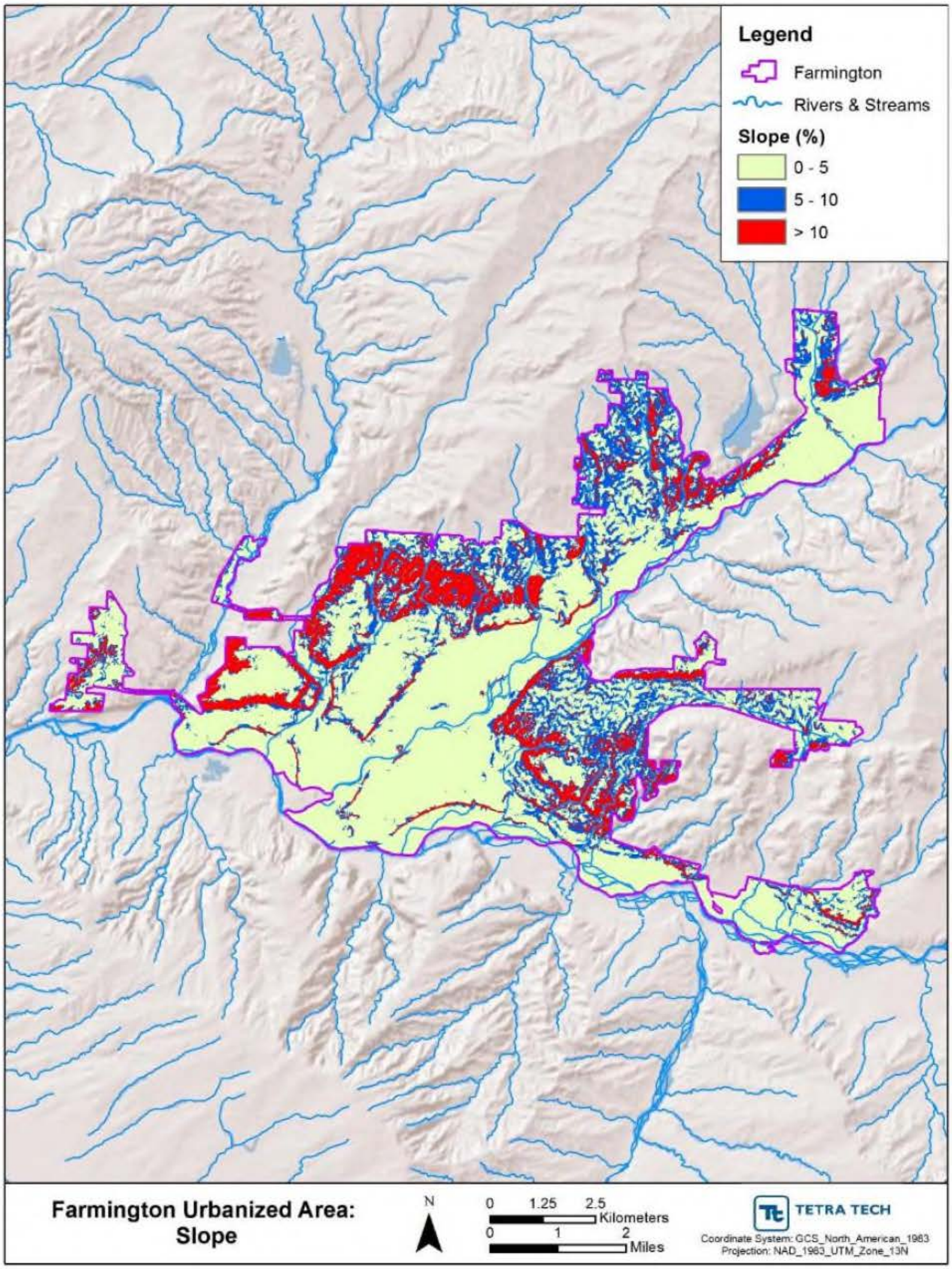
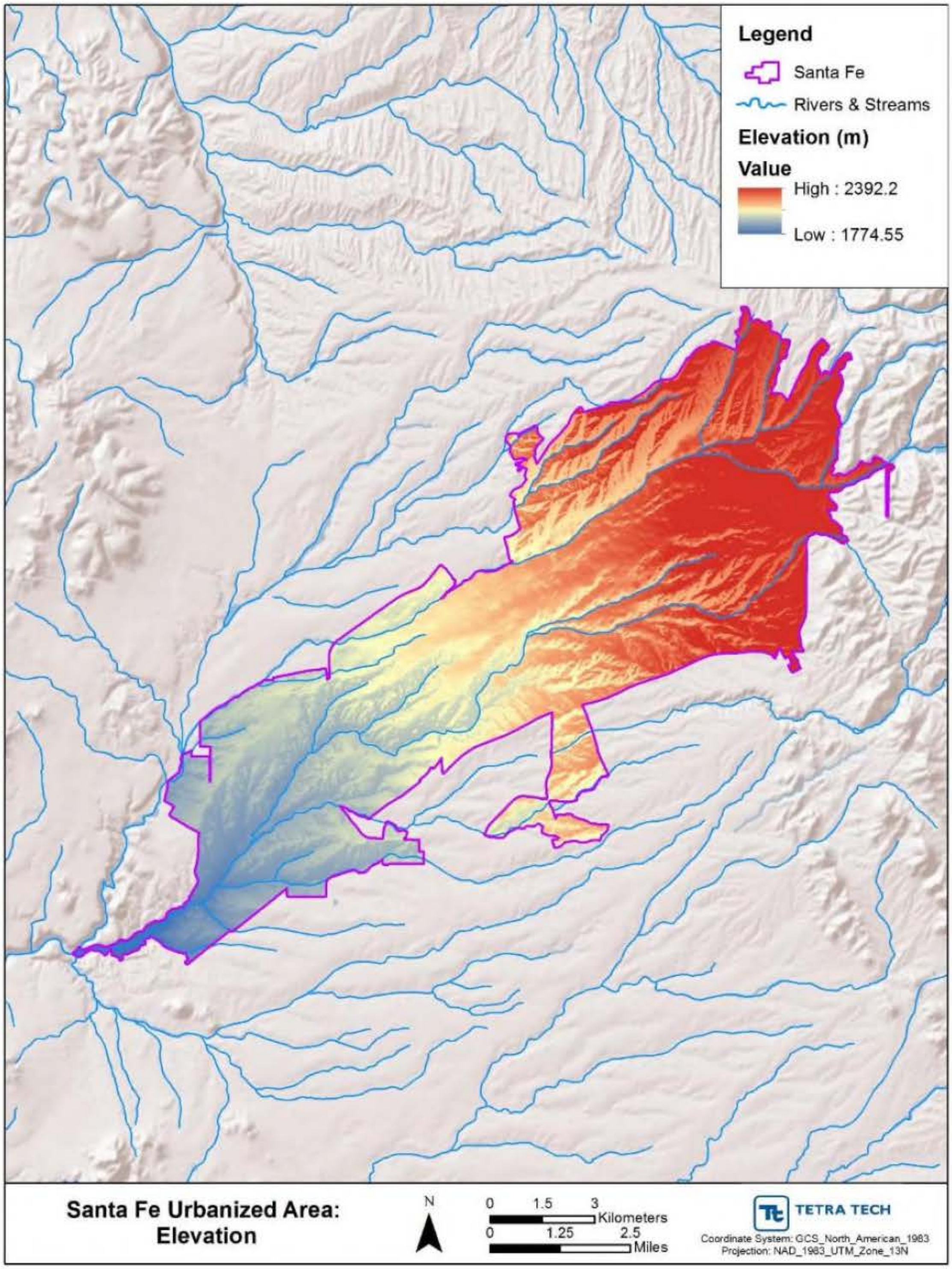
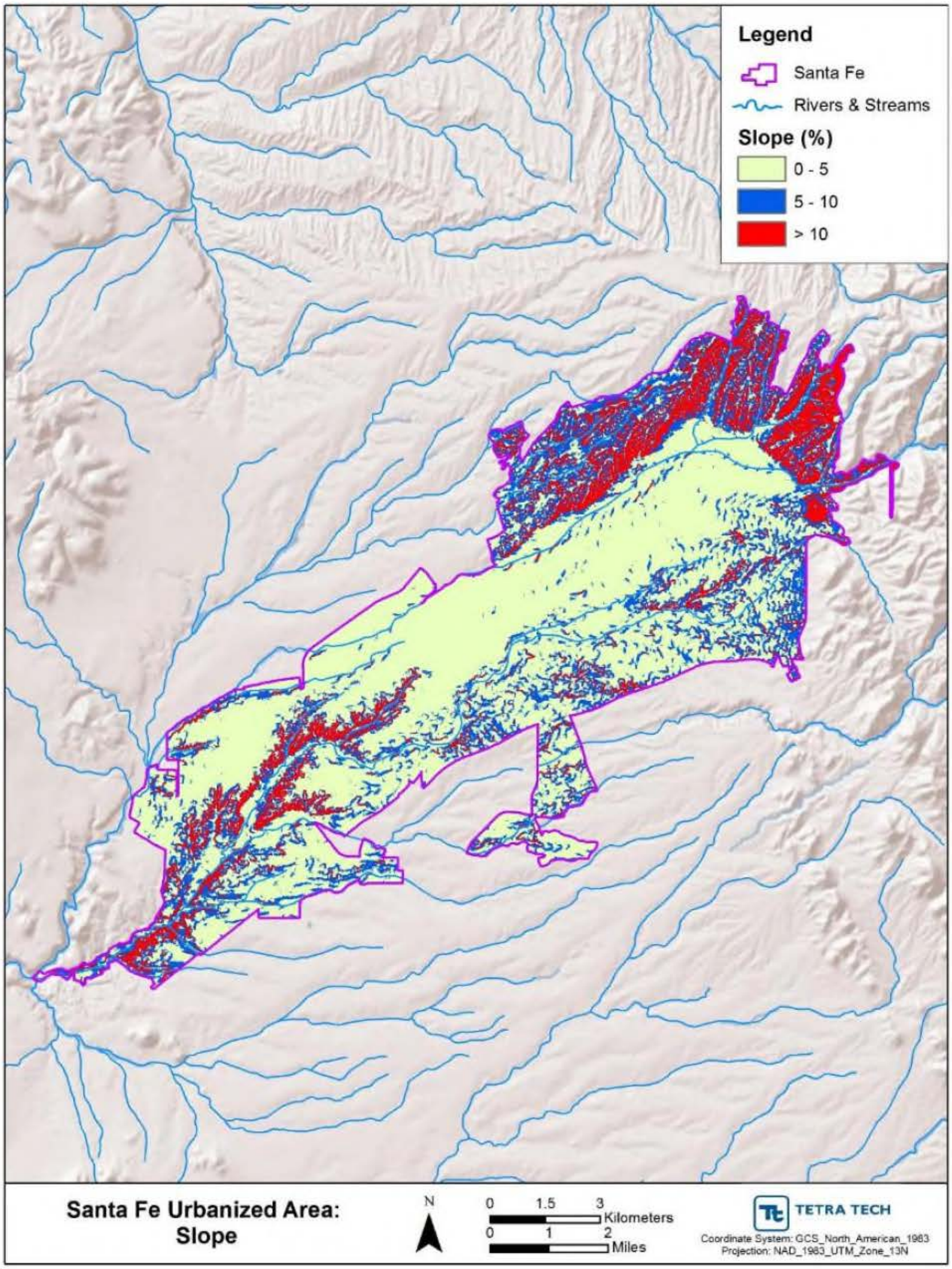
New Mexico
Texas
Santa Teresa
El Paso Airport
NCDC ID: 412797
United States
Mexico
Sunland Park
El Paso
El Paso Urbanized Area
N
0 3.25 6.5 Kilometers
0 2.75 5.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

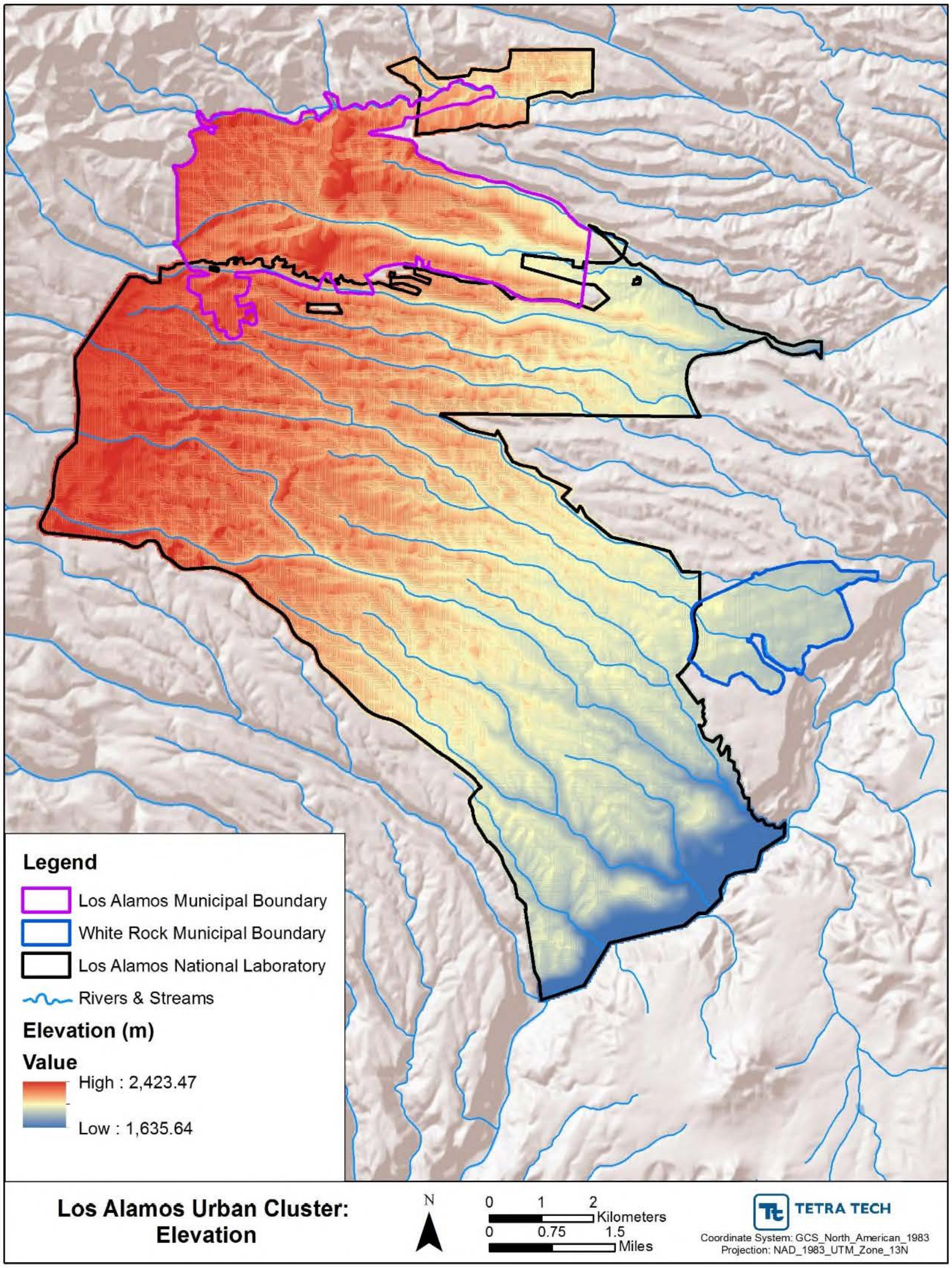
Appendix B Elevation and Slope

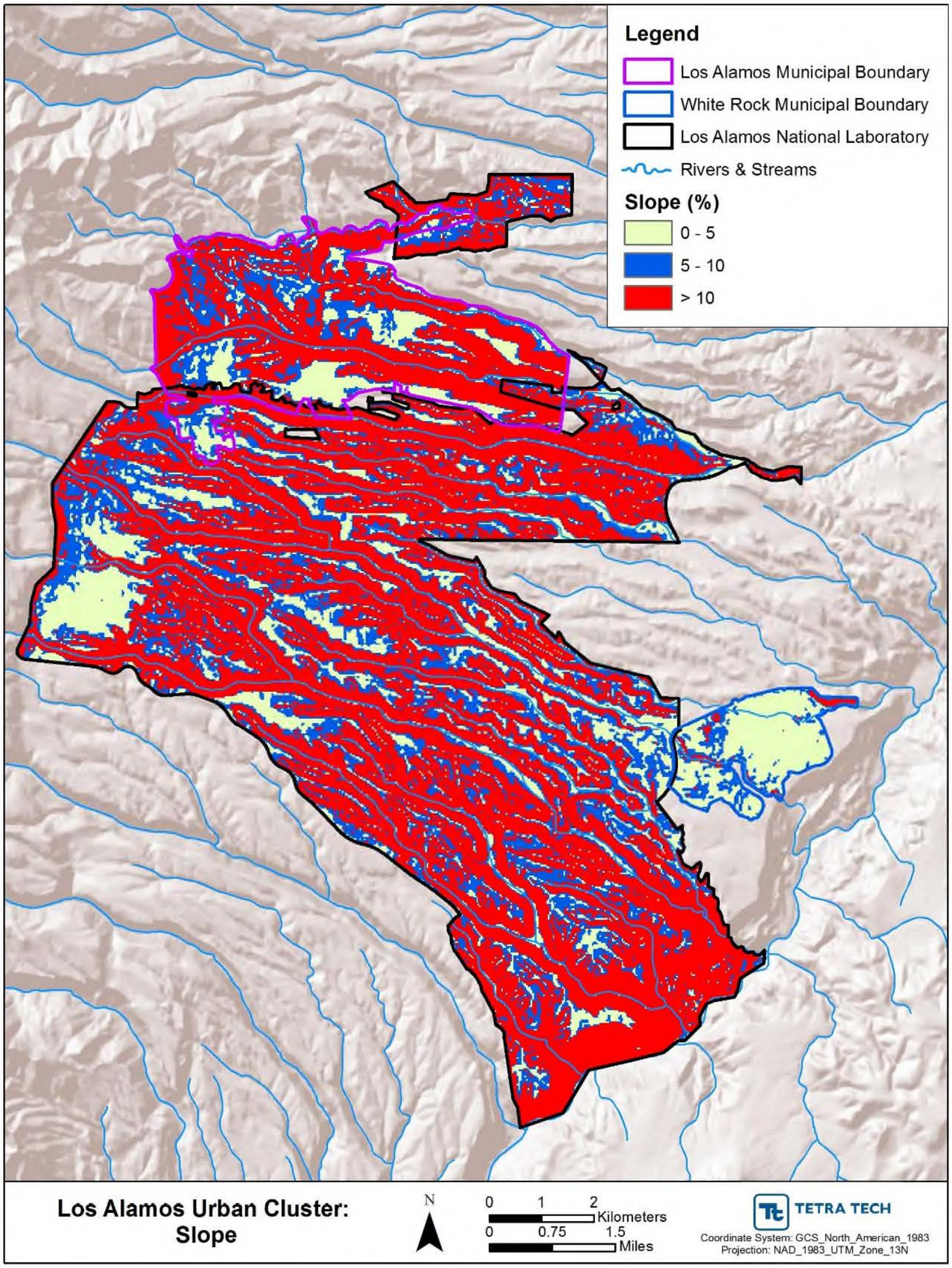

Legend
Farmington
Rivers & Streams
Elevation (m)
Value
High : 1805.32
Low : 1588.45
Farmington Urbanized Area:
Elevation
N
0 1.25 2.5
Kilometers
0 1 2
Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

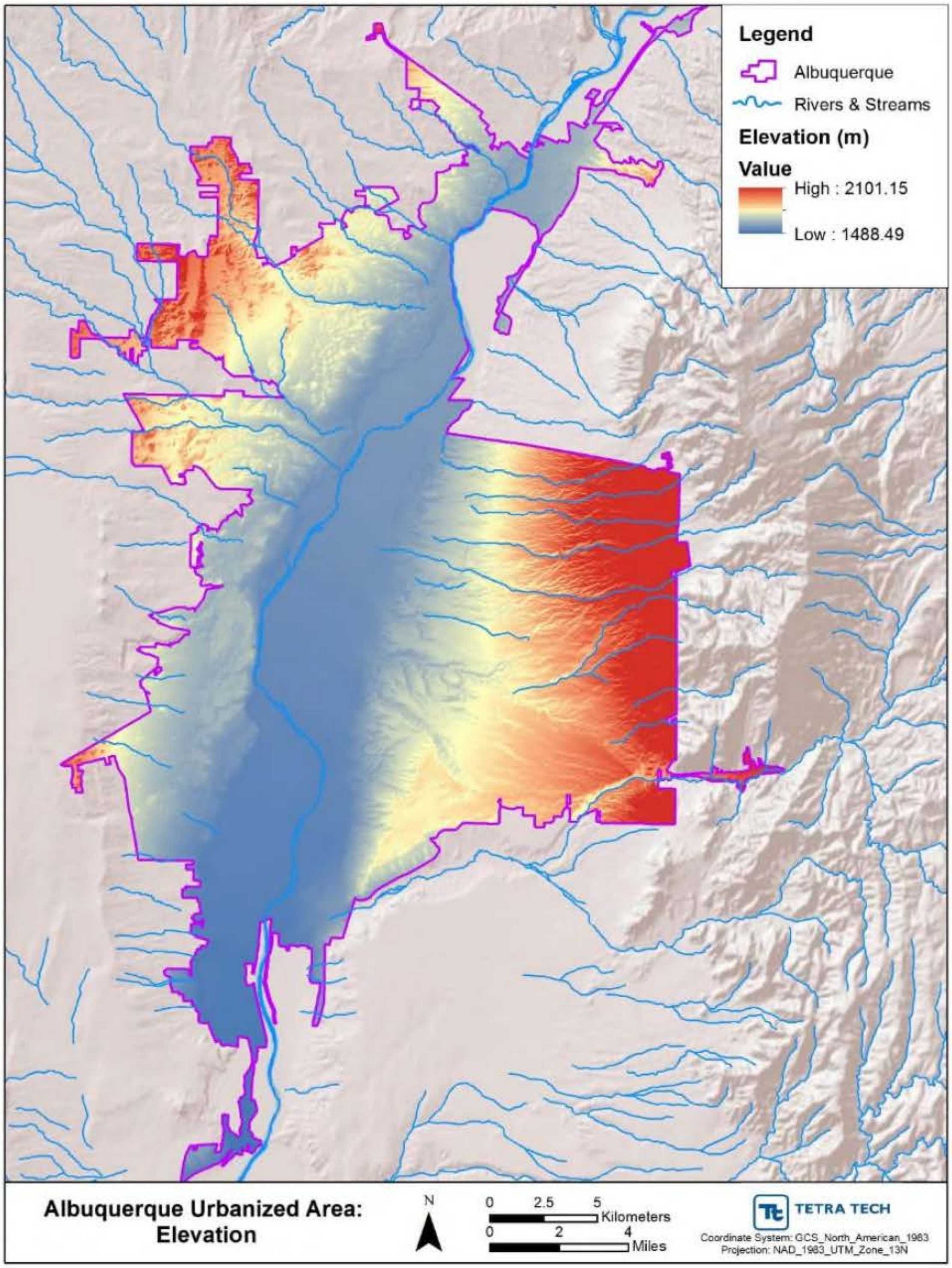

Legend
Farmington
Rivers & Streams
Slope (%)
0 - 5
5 - 10
> 10
Farmington Urbanized Area:
Slope
N
0 1.25 2.5
Kilometers
0 1 2
Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

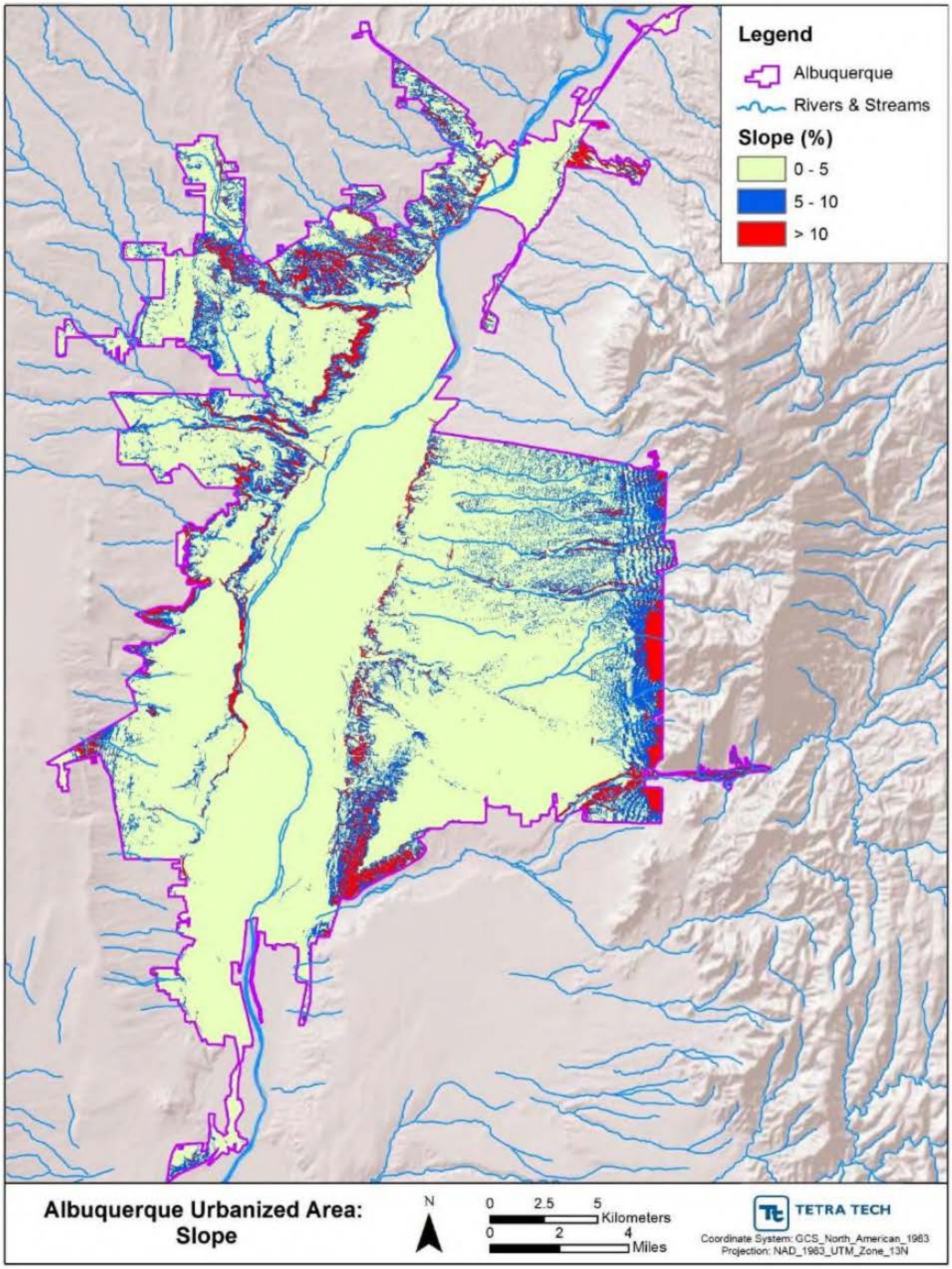

Legend
Santa Fe
Rivers & Streams
Elevation (m)
Value
High : 2392.2
Low : 1774.55
Santa Fe Urbanized Area:
Elevation
N
0 1.5 3 Kilometers
0 1.25 2.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

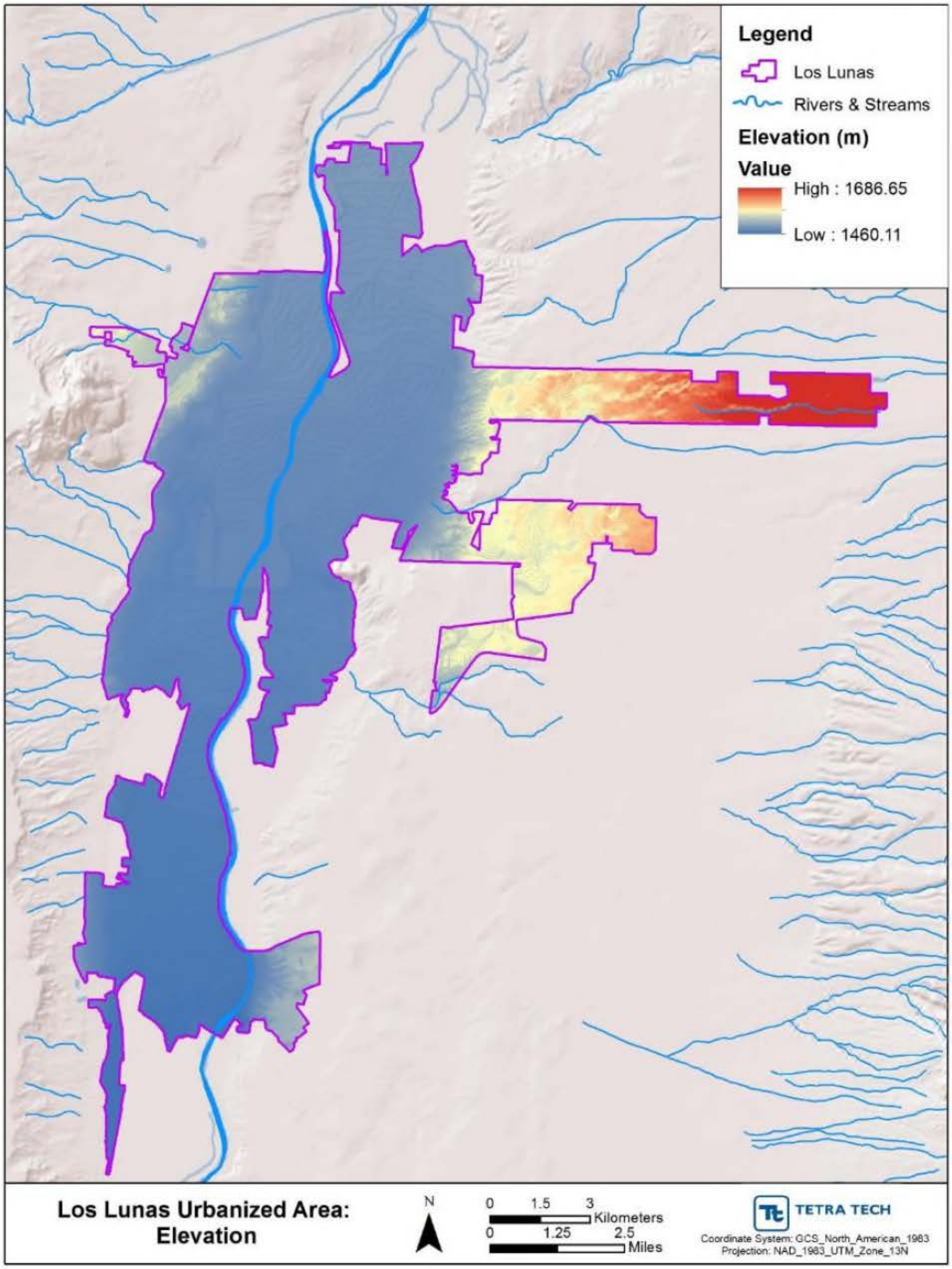

Legend
Santa Fe
Rivers & Streams
Slope (%)
0 - 5
5 - 10
> 10
Santa Fe Urbanized Area:
Slope
N
0
1.5
3
Kilometers
0
1
2
Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

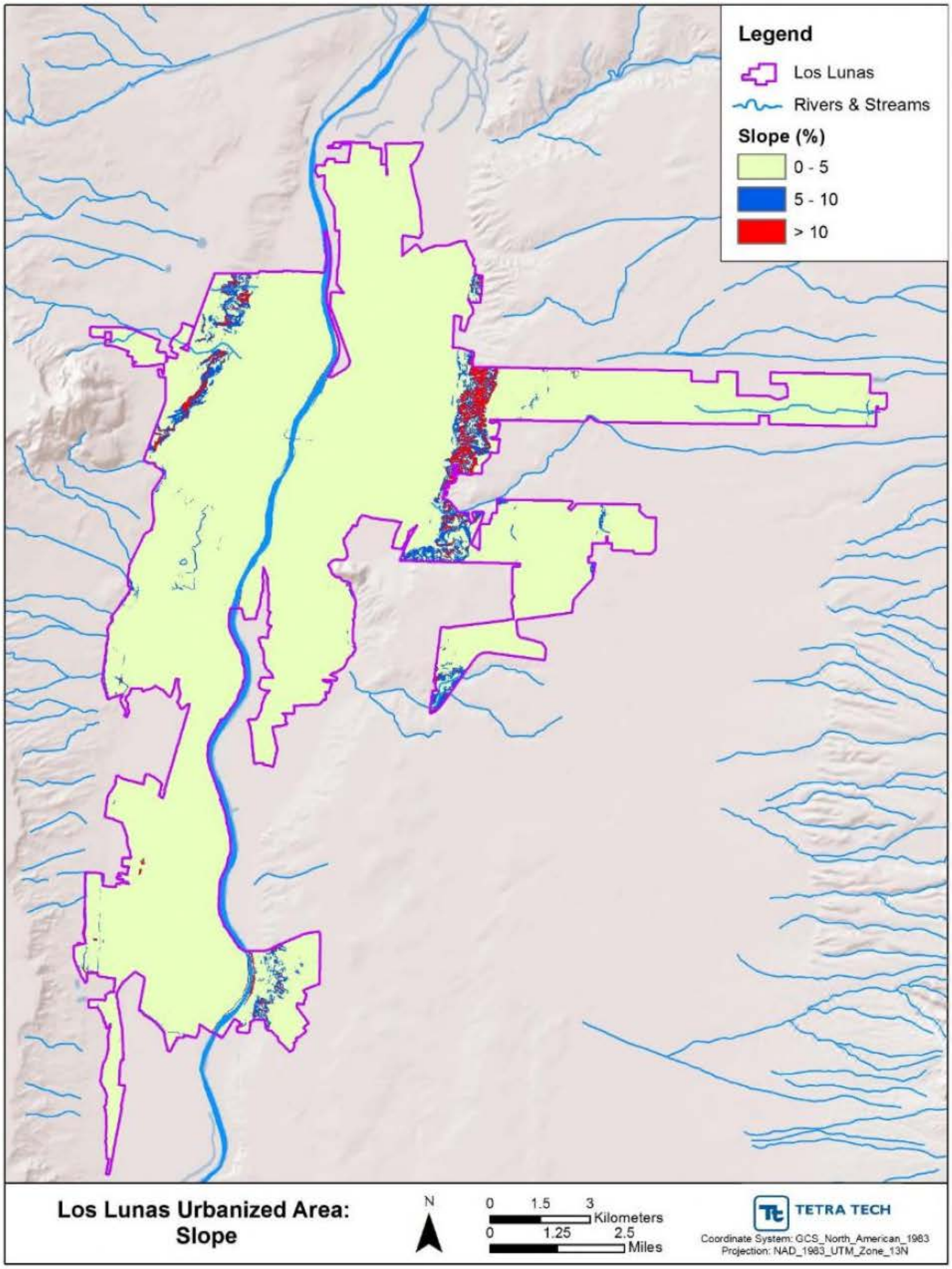

Legend
Los Alamos Municipal Boundary
White Rock Municipal Boundary
Los Alamos National Laboratory
Rivers & Streams
Elevation (m)
Value
High : 2,423.47
Low : 1,635.64
Los Alamos Urban Cluster: Elevation
N
0 1 2 Kilometers
0 0.75 1.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

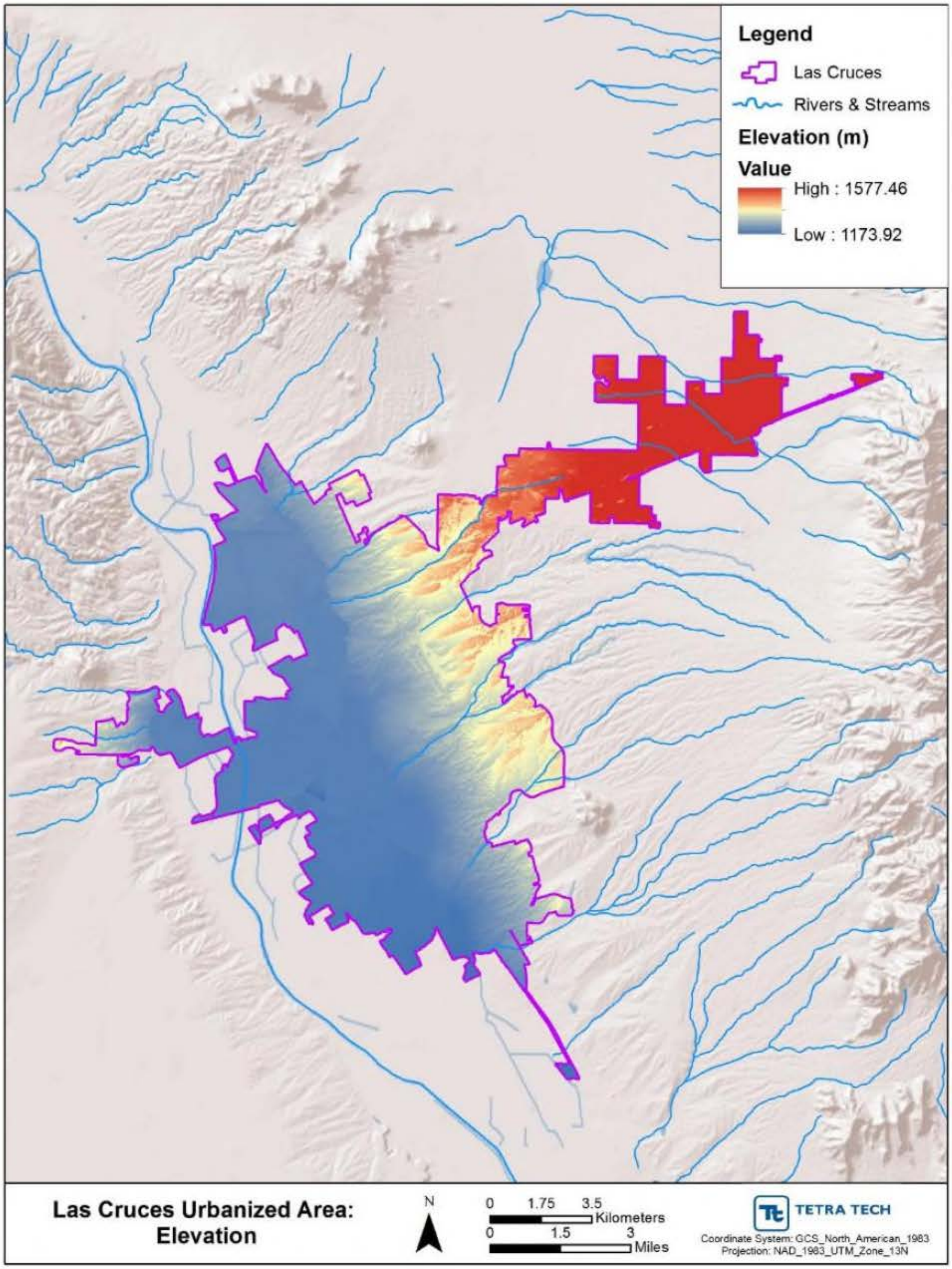

Legend
Los Alamos Municipal Boundary
White Rock Municipal Boundary
Los Alamos National Laboratory
Rivers & Streams
Slope (%)
0 - 5
5 - 10
> 10
Los Alamos Urban Cluster:
Slope
N
0 1 2
Kilometers
0 0.75 1.5
Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

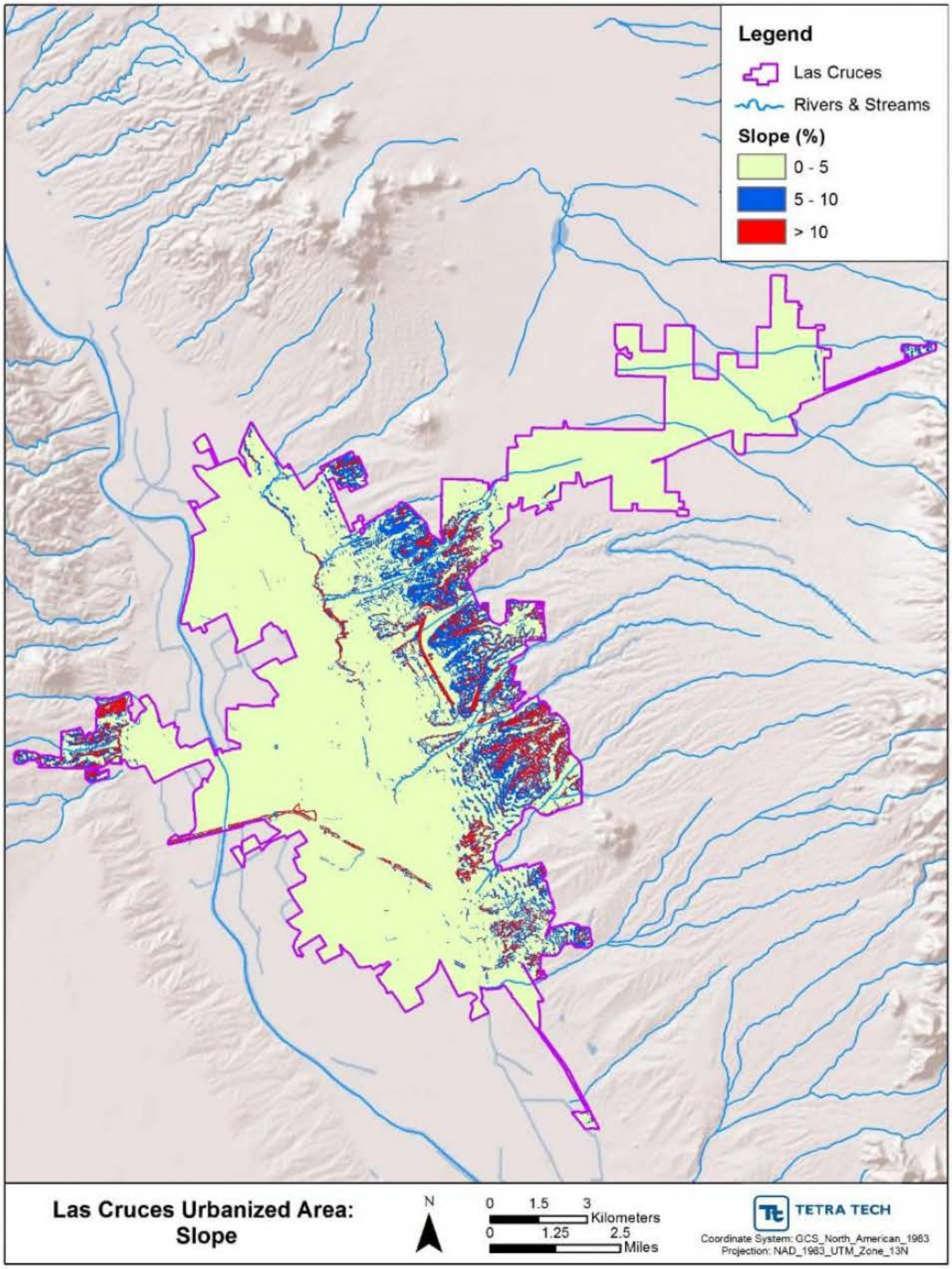

Legend
Albuquerque
Rivers & Streams
Elevation (m)
Value
High : 2101.15
Low : 1488.49
Albuquerque Urbanized Area: Elevation
N
0 2.5 5 Kilometers
0 2 4 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

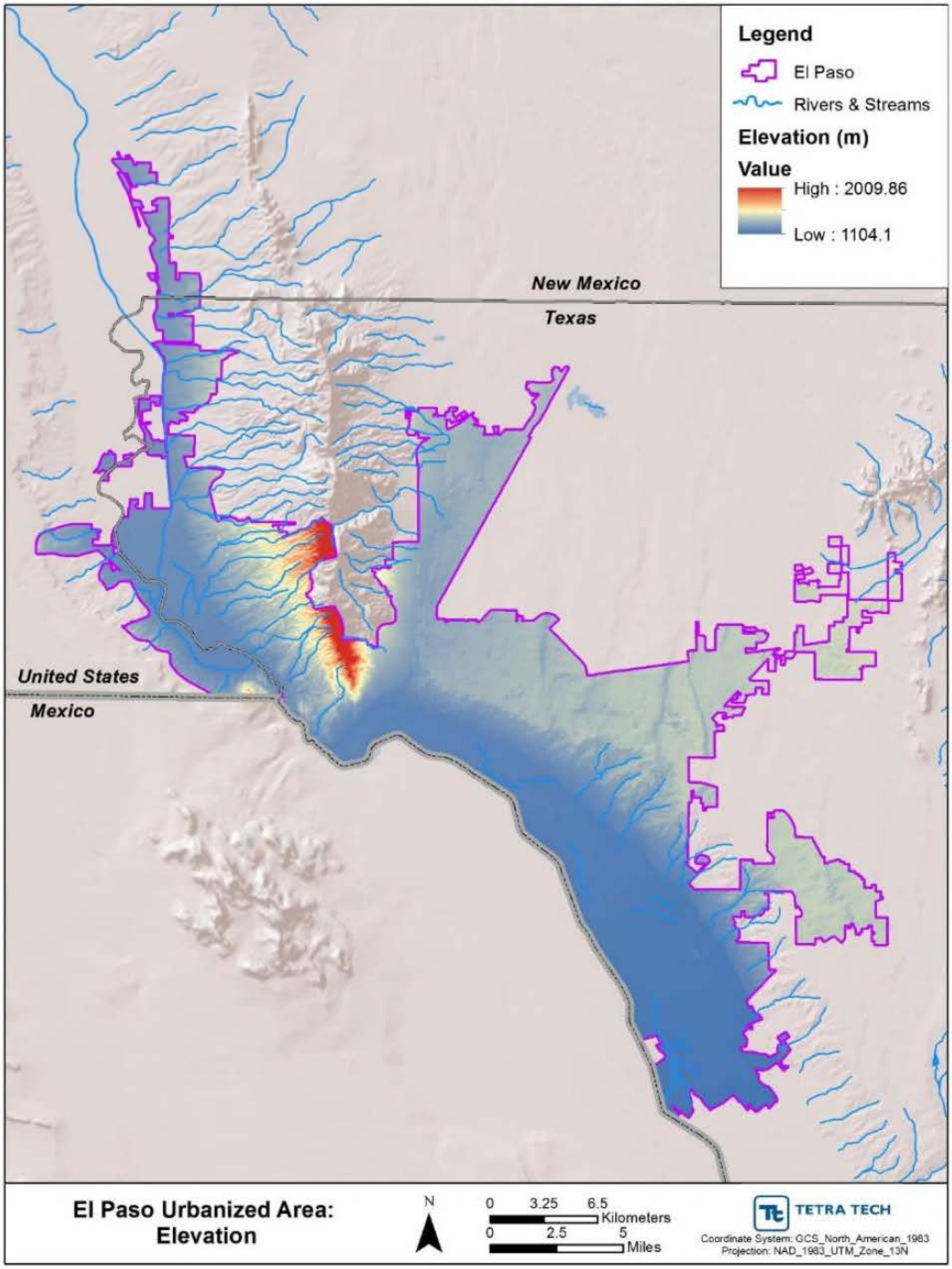

Legend
Albuquerque
Rivers & Streams
Slope (%)
0 - 5
5 - 10
> 10
Albuquerque Urbanized Area:
Slope
N
0 2.5 5 Kilometers
0 2 4 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

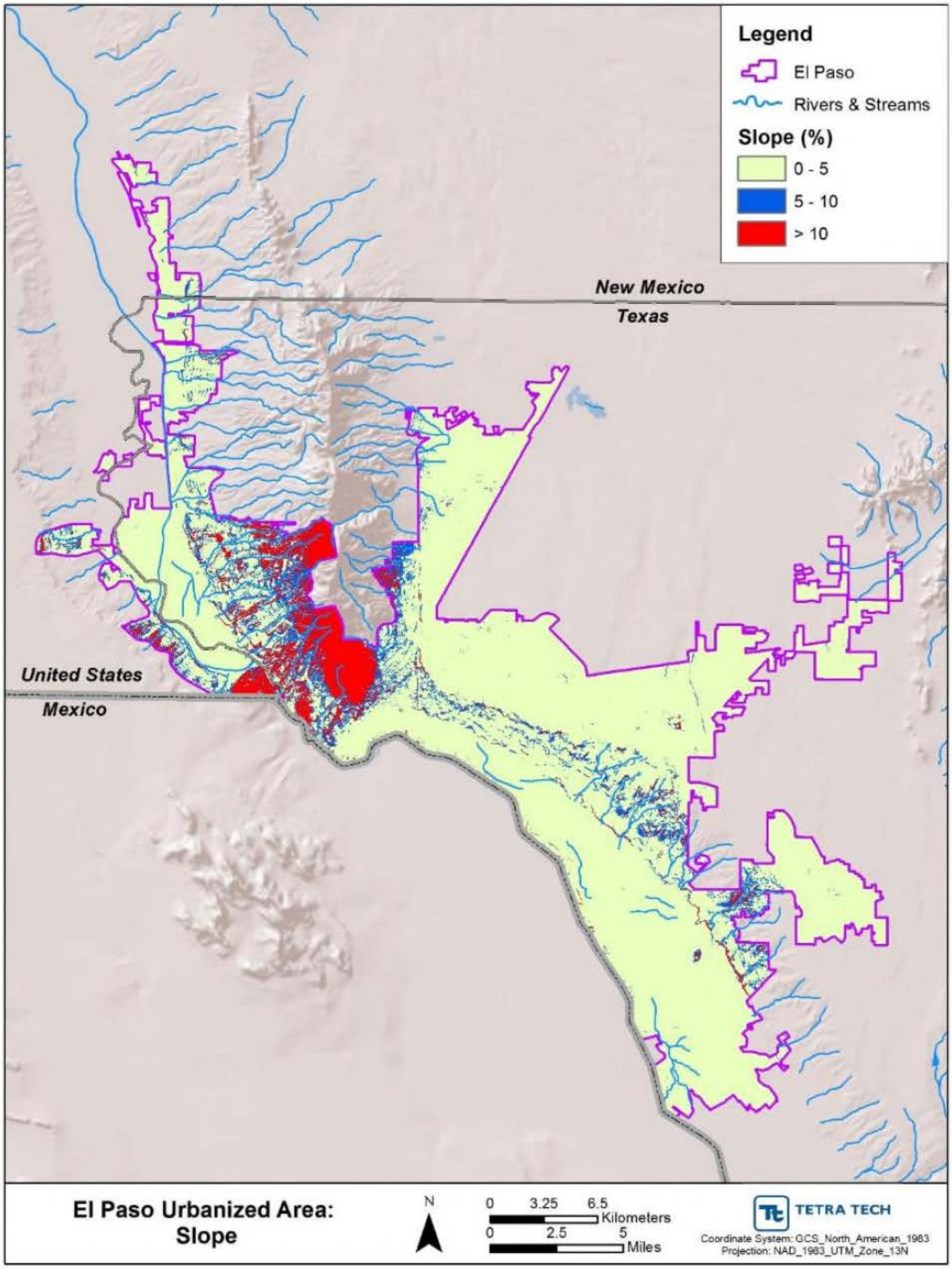

Legend
Los Lunas
Rivers & Streams
Elevation (m)
Value
High : 1686.65
Low : 1460.11
Los Lunas Urbanized Area:
Elevation
N
0 1.5 3
Kilometers
0 1.25 2.5
Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N


Legend
Los Lunas
Rivers & Streams
Slope (%)
0 - 5
5 - 10
> 10
Los Lunas Urbanized Area:
Slope
N
0 1.5 3 Kilometers
0 1.25 2.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

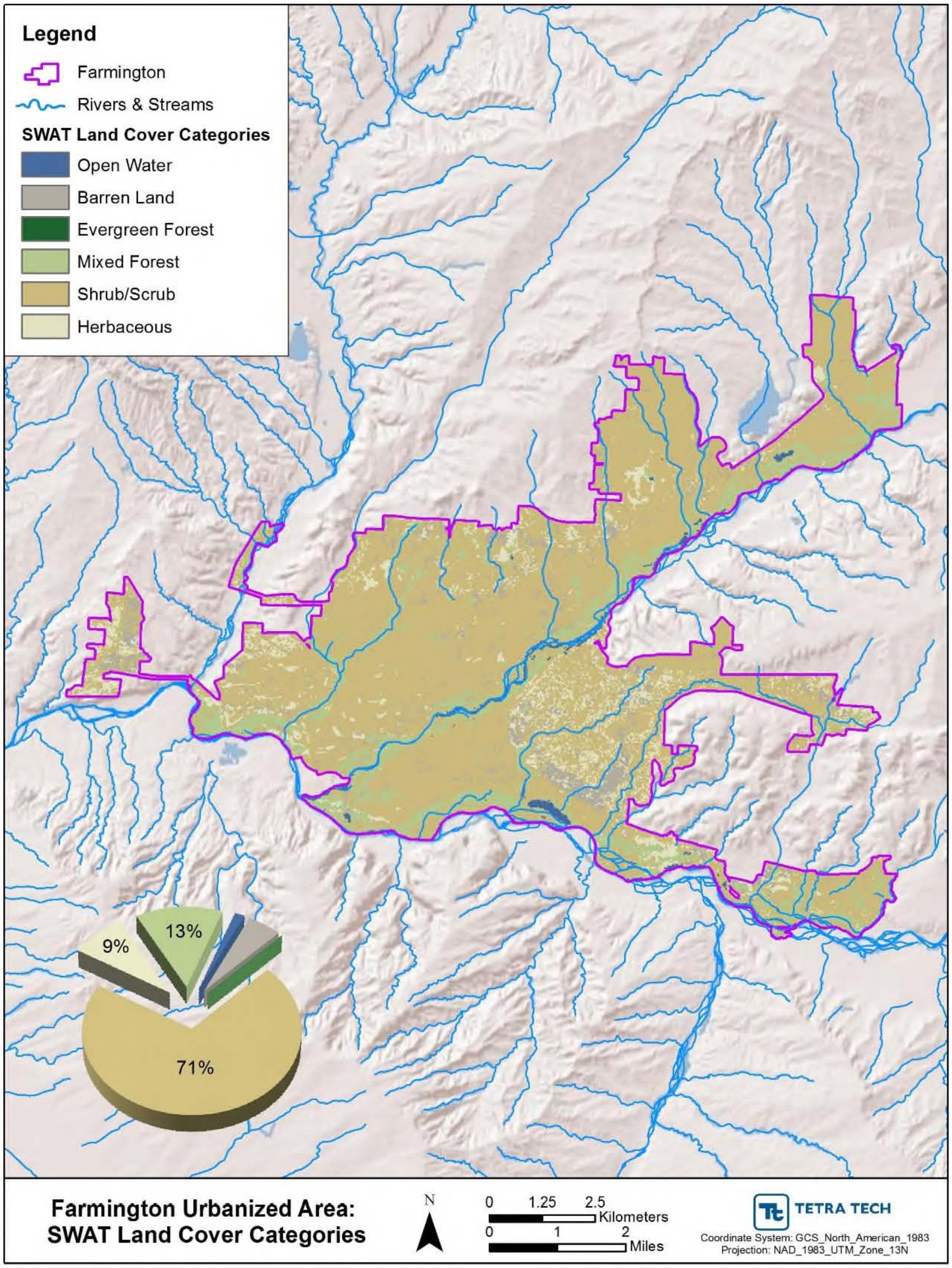

Legend
Las Cruces
Rivers & Streams
Elevation (m)
Value
High : 1577.46
Low : 1173.92
Las Cruces Urbanized Area: Elevation
N
0 1.75 3.5 Kilometers
0 1.5 3 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

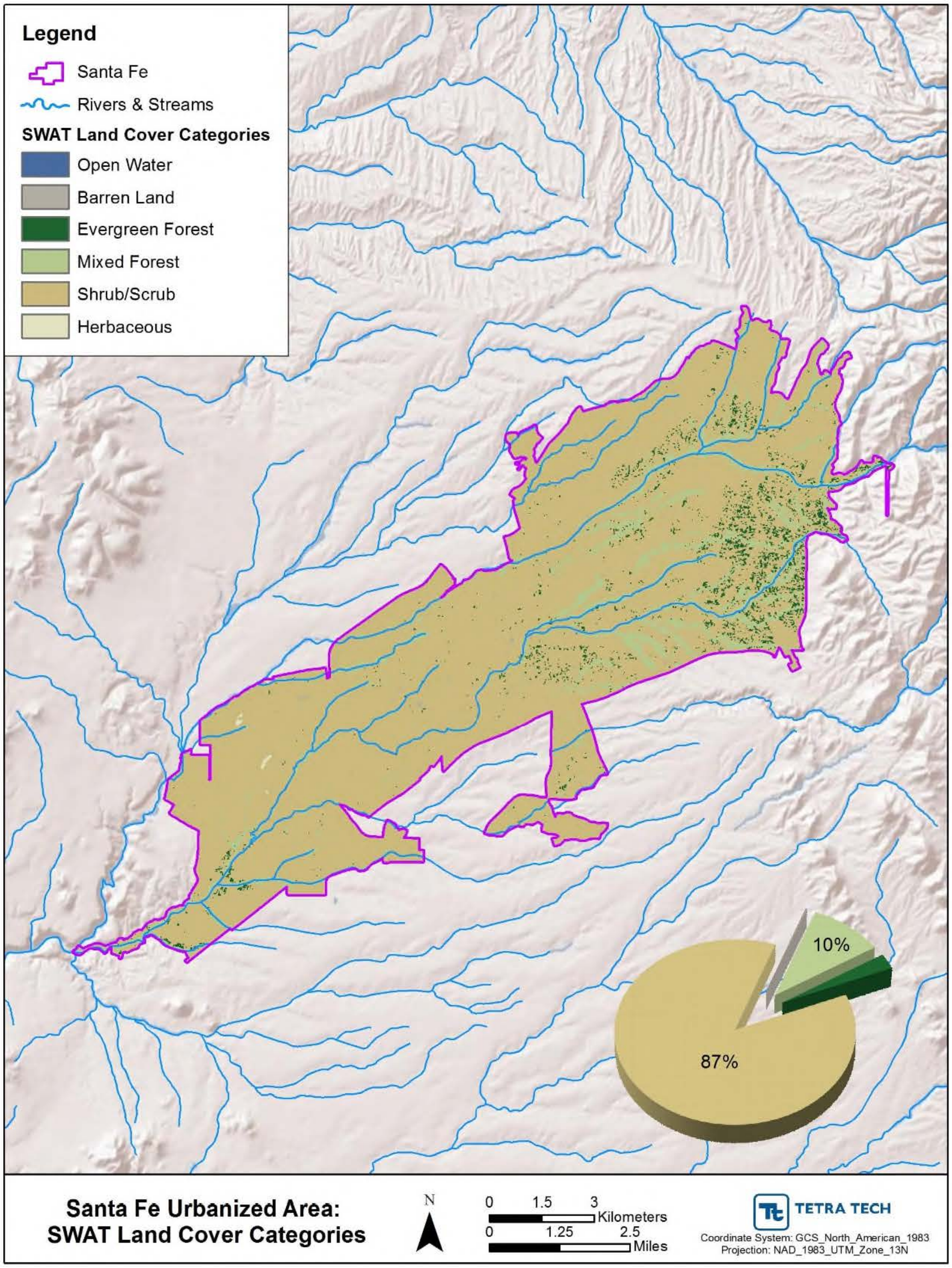

Legend
Las Cruces
Rivers & Streams
Slope (%)
0 - 5
5 - 10
> 10
Las Cruces Urbanized Area:
Slope
N
0 1.5 3
Kilometers
0 1.25 2.5
Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

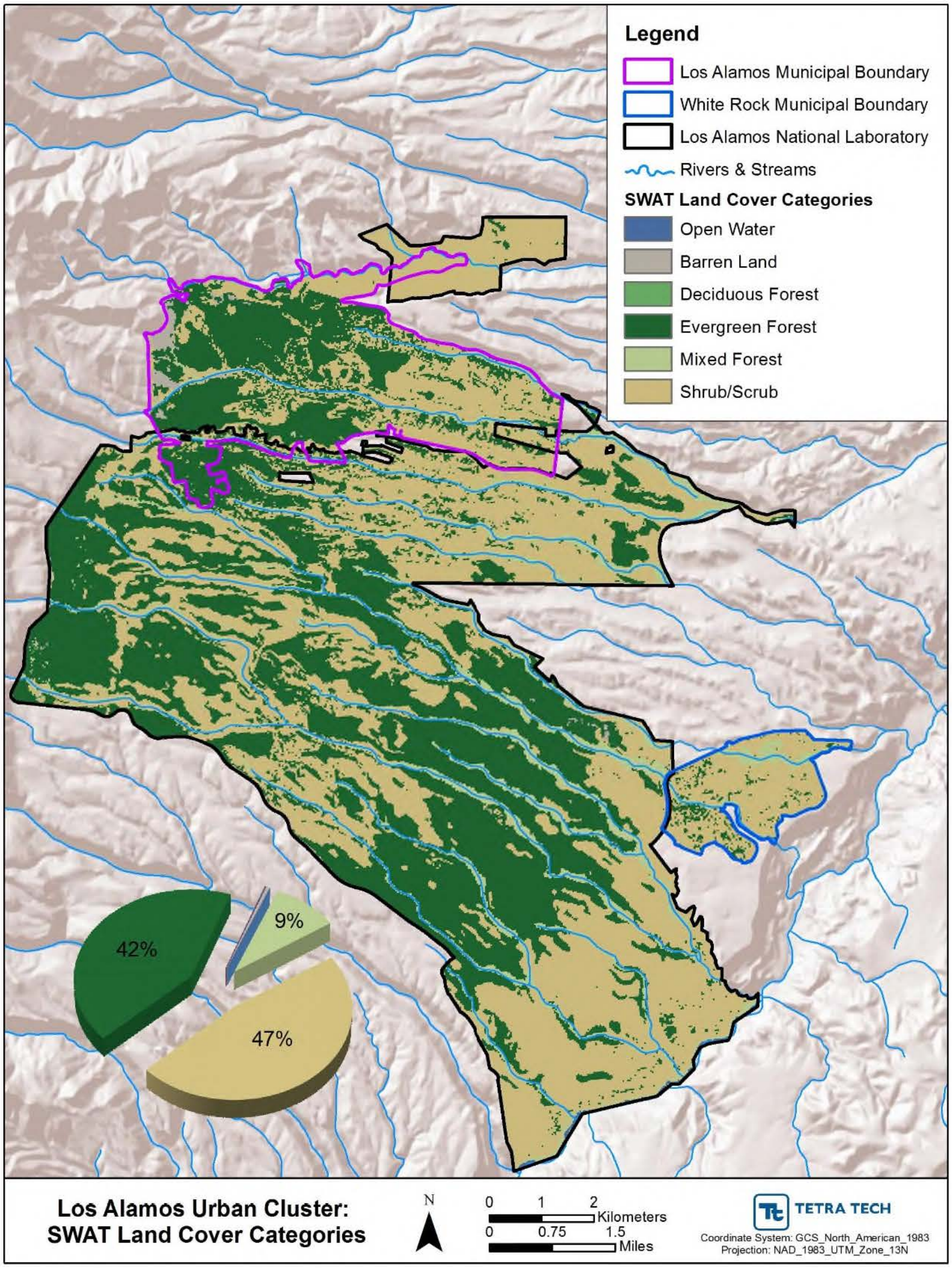

Legend
El Paso
Rivers & Streams
Elevation (m)
Value
High : 2009.86
Low : 1104.1
New Mexico
Texas
United States
Mexico
El Paso Urbanized Area: Elevation
N
0 3.25 6.5 Kilometers
0 2.5 5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

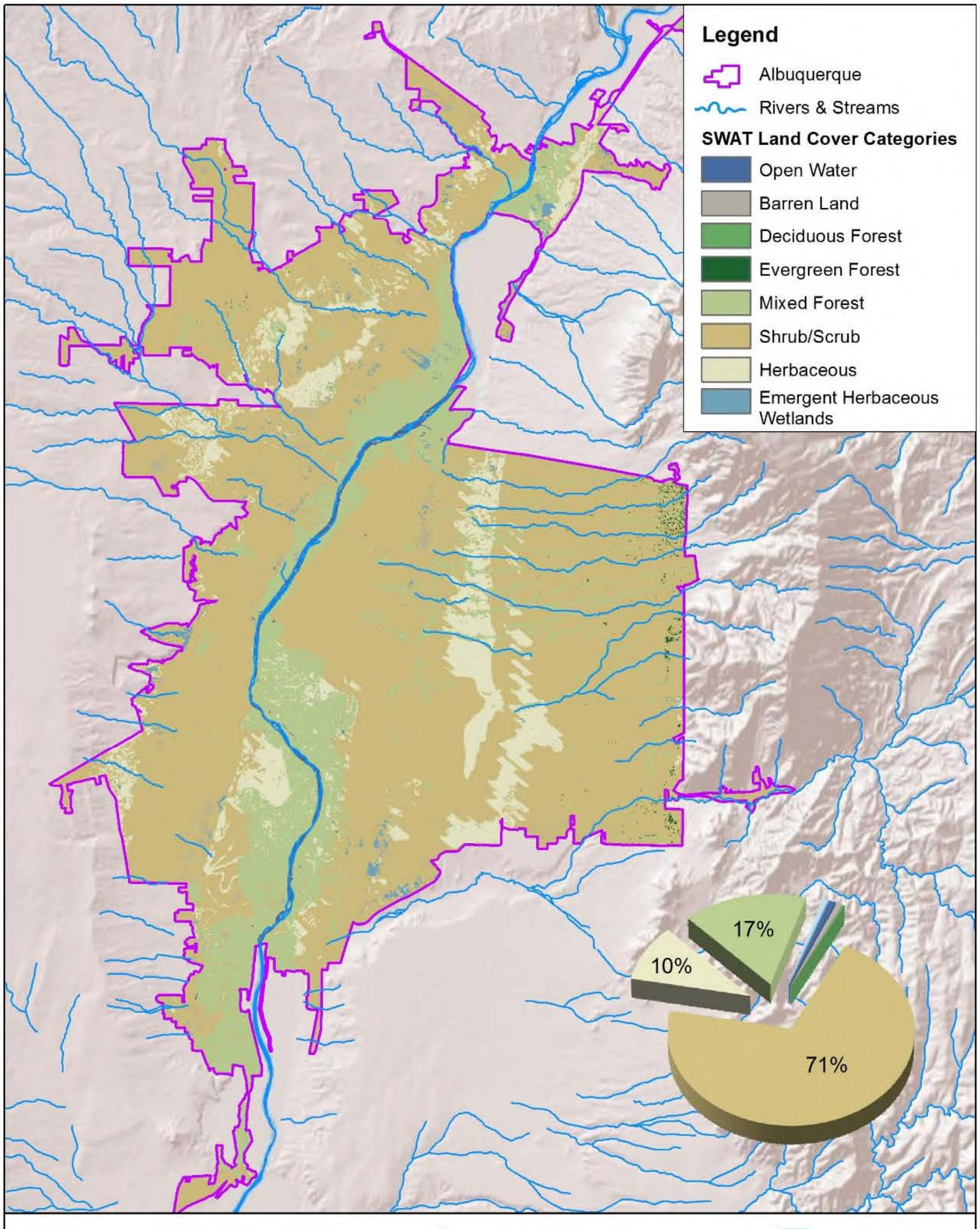

Legend
El Paso
Rivers & Streams
Slope (%)
0 - 5
5 - 10
> 10
New Mexico
Texas
United States
Mexico
El Paso Urbanized Area:
Slope
N
0 3.25 6.5 Kilometers
0 2.5 5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

Appendix C Landuse

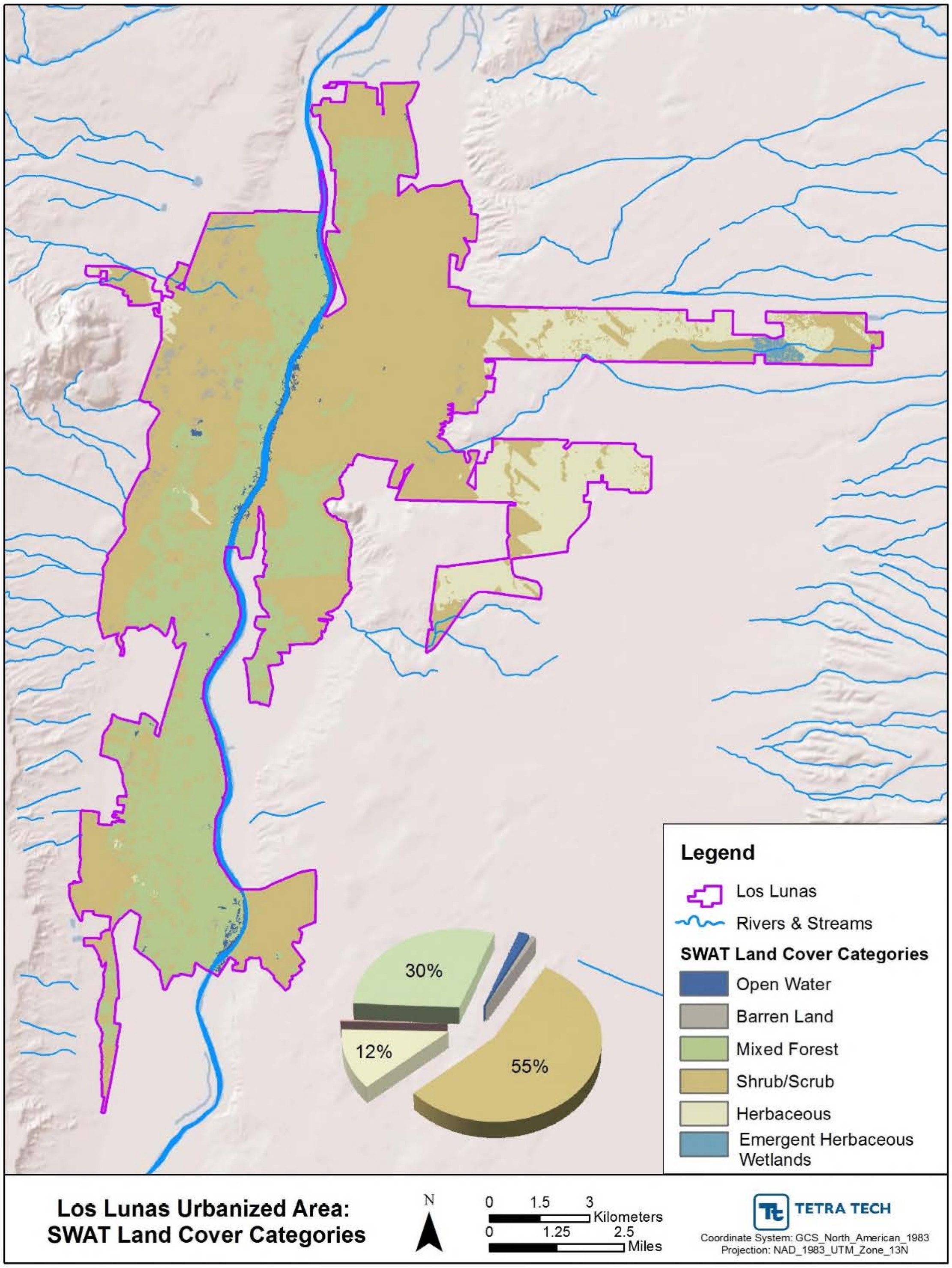

Legend
Farmington
Rivers & Streams
SWAT Land Cover Categories
Open Water
Barren Land
Evergreen Forest
Mixed Forest
Shrub/Scrub
Herbaceous
13%
9%
71%
Farmington Urbanized Area:
SWAT Land Cover Categories
N
0 1.25 2.5 Kilometers
0 1 2 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

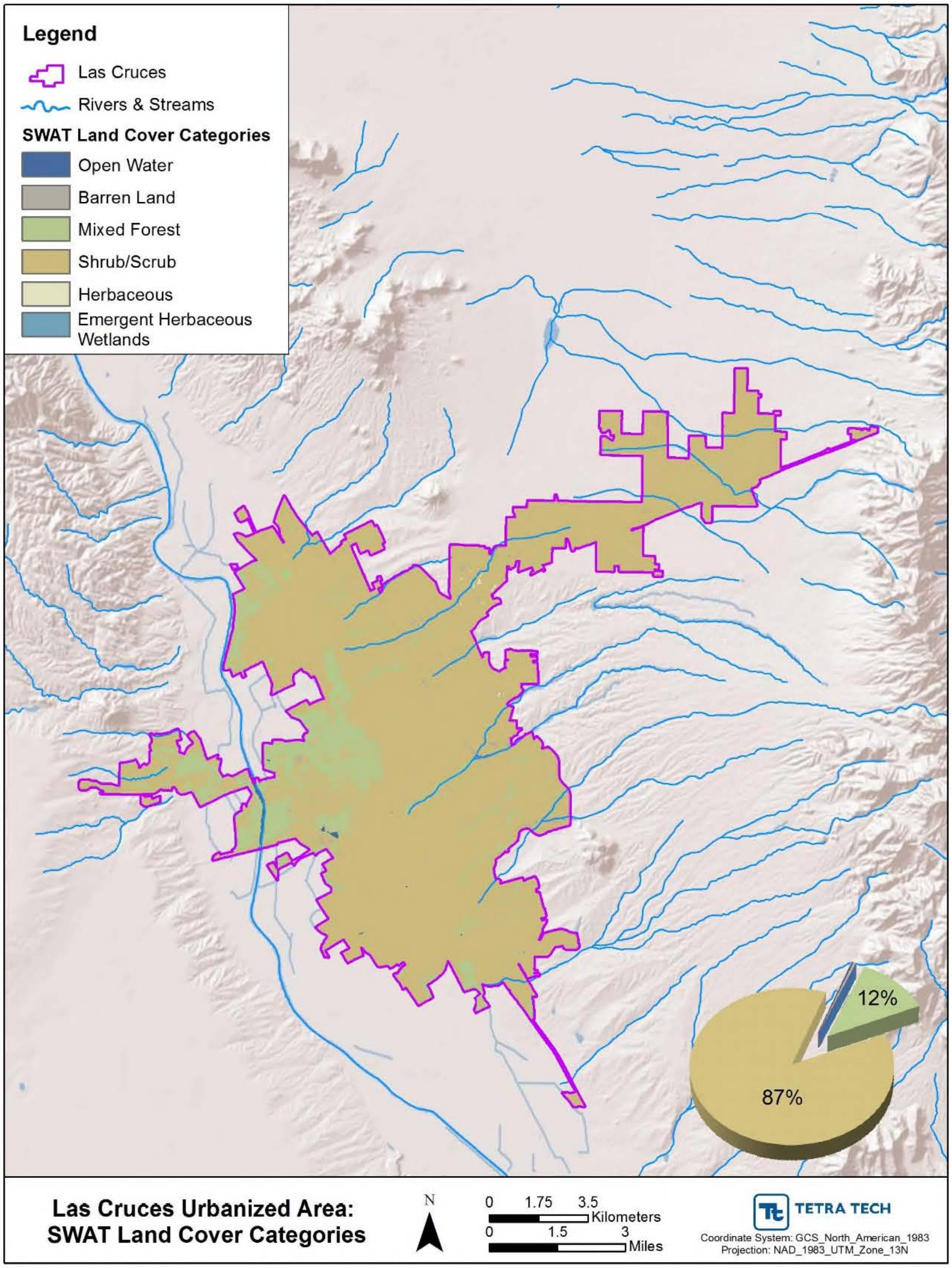

Legend
Santa Fe
Rivers & Streams
SWAT Land Cover Categories
Open Water
Barren Land
Evergreen Forest
Mixed Forest
Shrub/Scrub
Herbaceous
10%
87%
Santa Fe Urbanized Area:
SWAT Land Cover Categories
N
0 1.5 3 Kilometers
0 1.25 2.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

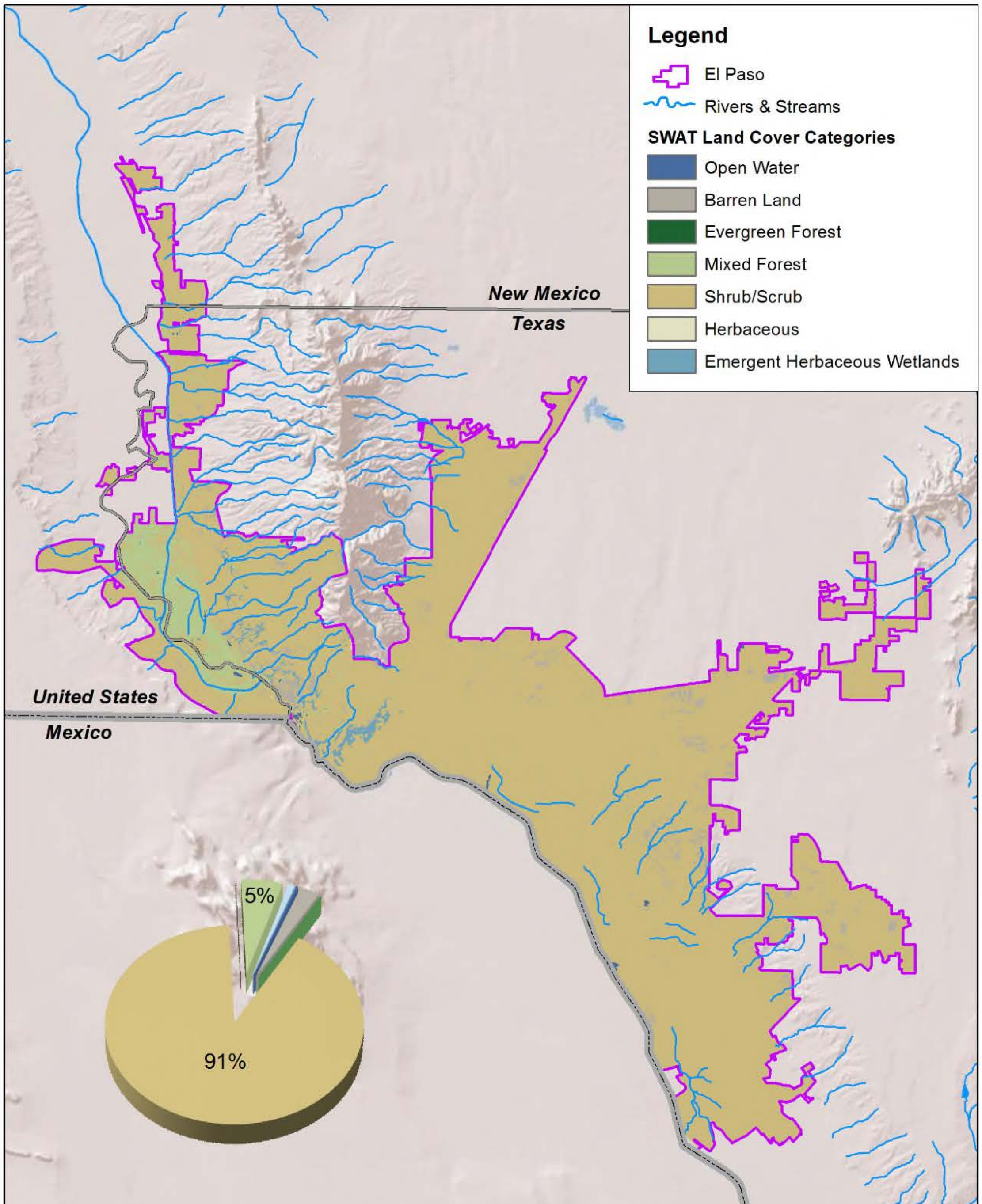

Legend
Los Alamos Municipal Boundary
White Rock Municipal Boundary
Los Alamos National Laboratory
Rivers & Streams
SWAT Land Cover Categories
Open Water
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
9%
42%
47%
Los Alamos Urban Cluster:
SWAT Land Cover Categories
N
0 1 2 Kilometers
0 0.75 1.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N



Albuquerque Urbanized Area: SWAT Land Cover Categories

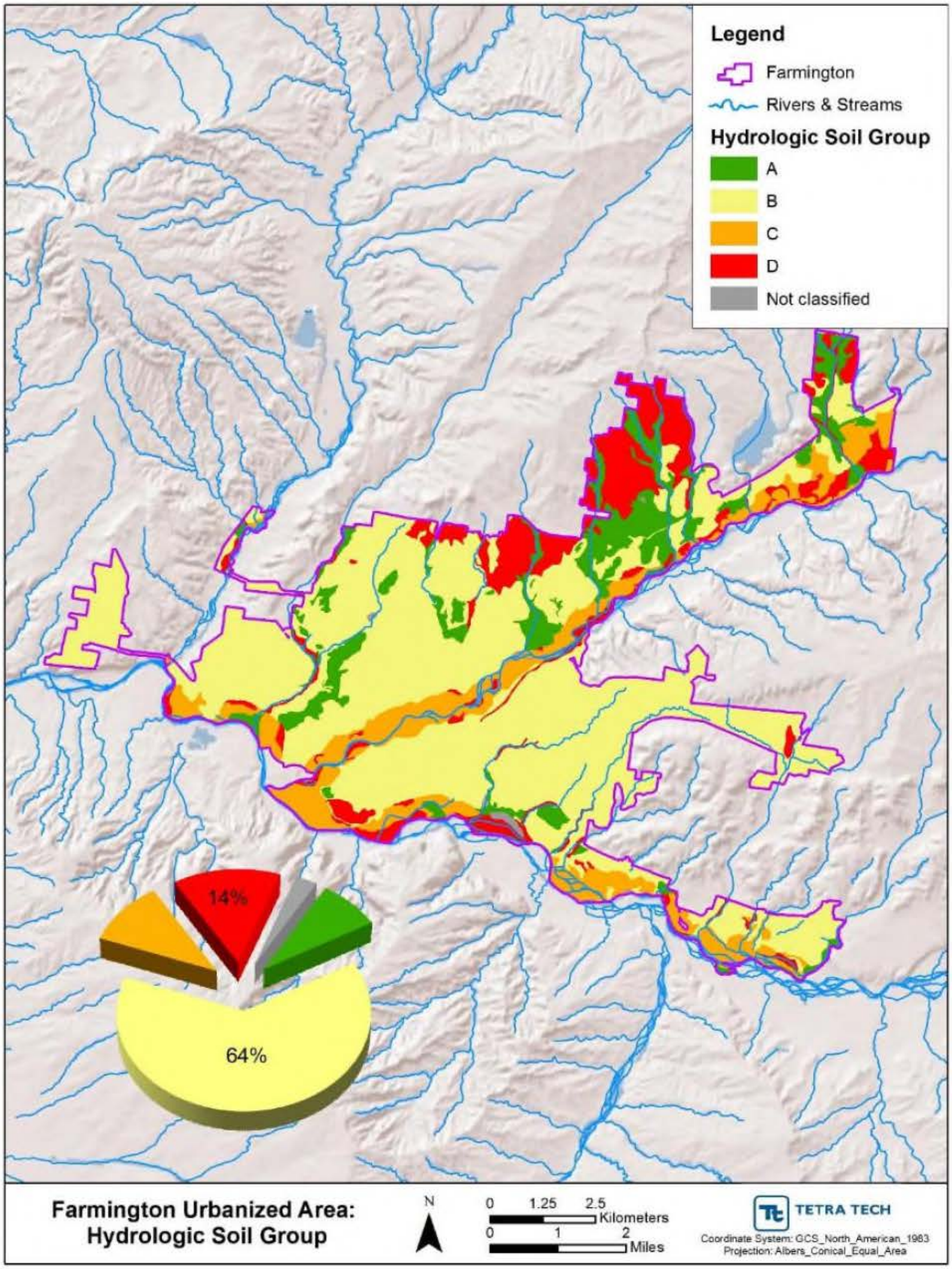

Legend
Los Lunas
Rivers & Streams
SWAT Land Cover Categories
Open Water
Barren Land
Mixed Forest
Shrub/Scrub
Herbaceous
Emergent Herbaceous Wetlands
30%
12%
55%
Los Lunas Urbanized Area:
SWAT Land Cover Categories
N
0 1.5 3 Kilometers
0 1.25 2.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

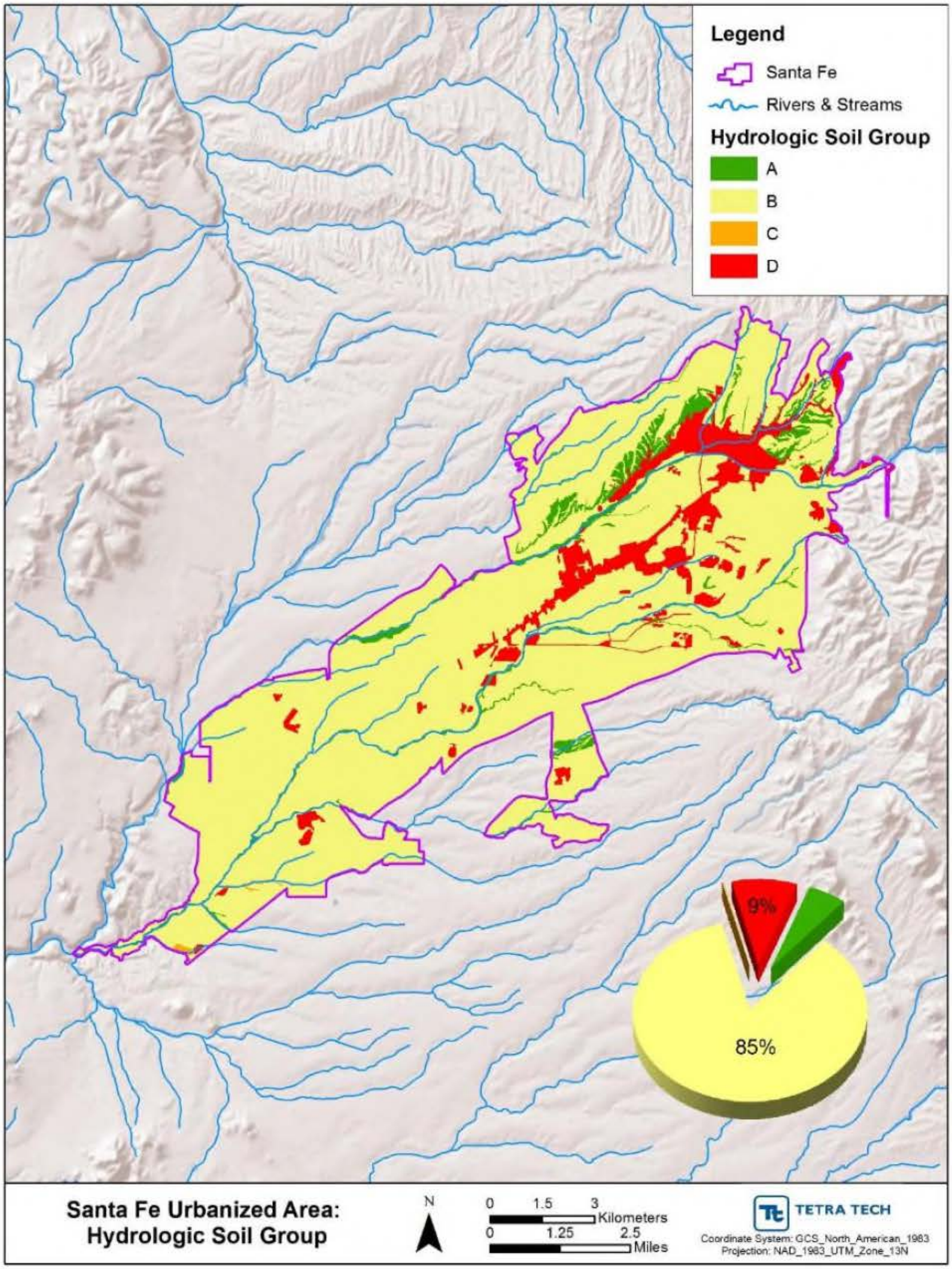

Legend
Las Cruces
Rivers & Streams
SWAT Land Cover Categories
Open Water
Barren Land
Mixed Forest
Shrub/Scrub
Herbaceous
Emergent Herbaceous Wetlands
12%
87%
Las Cruces Urbanized Area:
SWAT Land Cover Categories
N
0 1.75 3.5 Kilometers
0 1.5 3 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

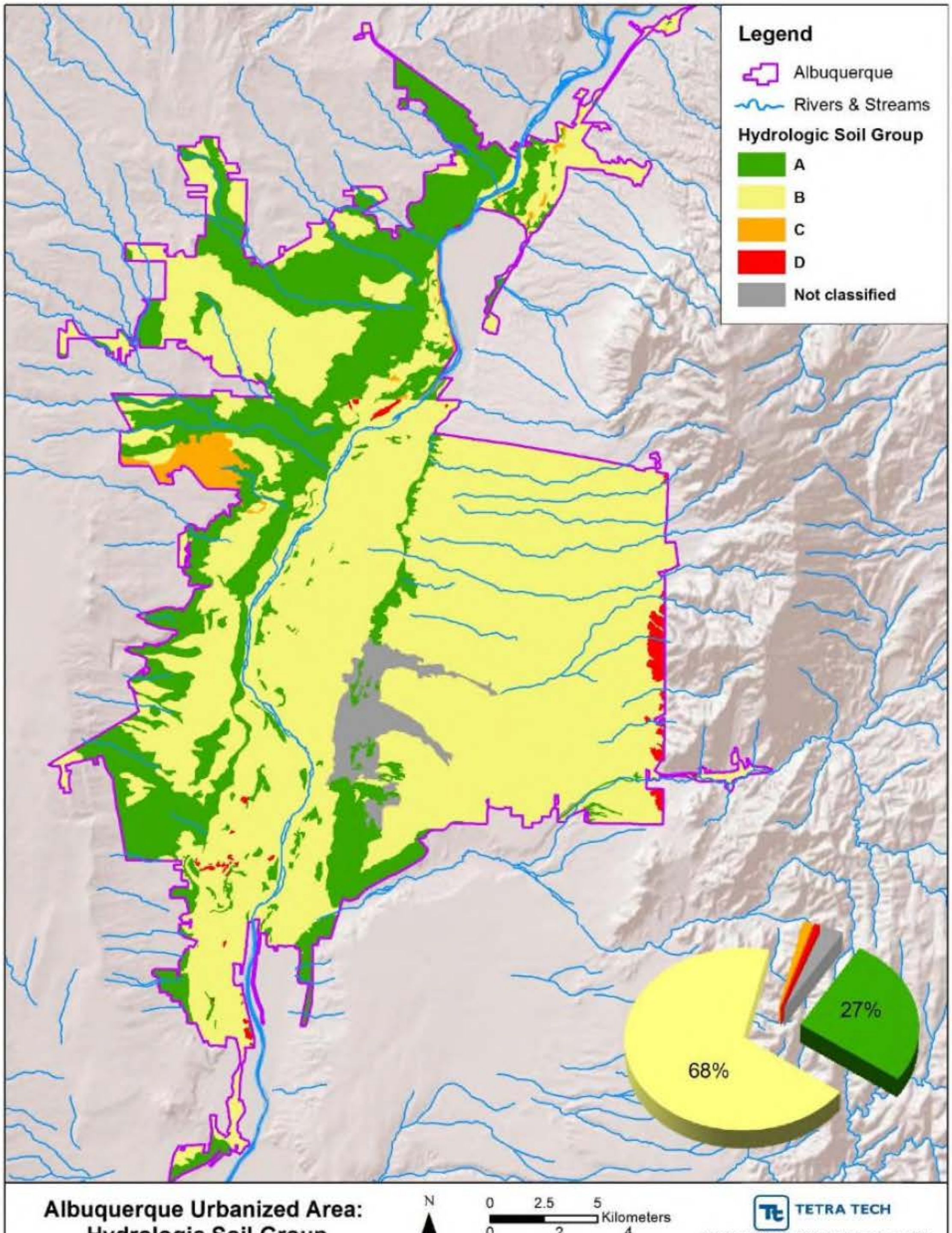


El Paso Urbanized Area: SWAT Land Cover Categories

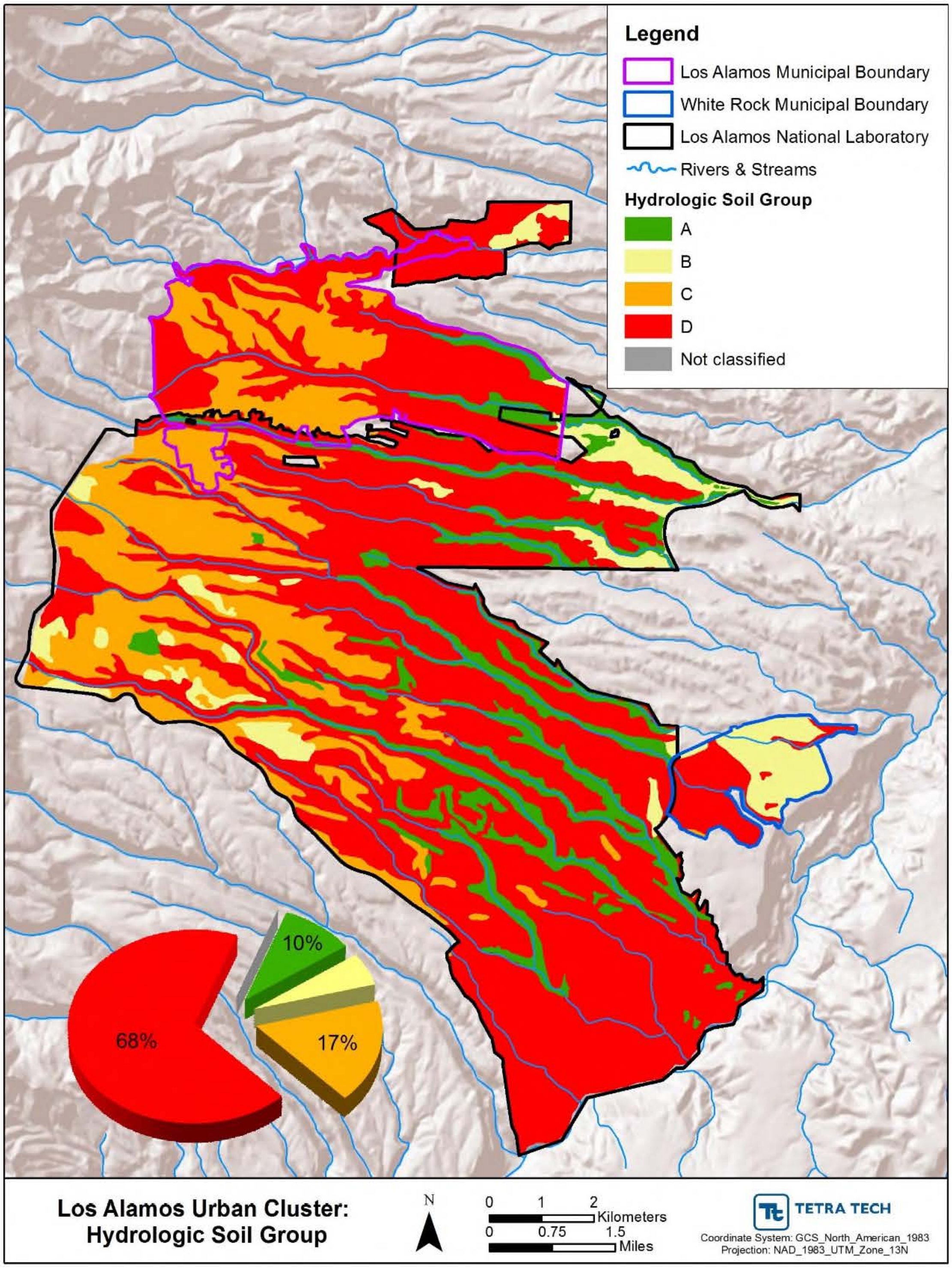
Appendix D Hydrologic Soil Groups

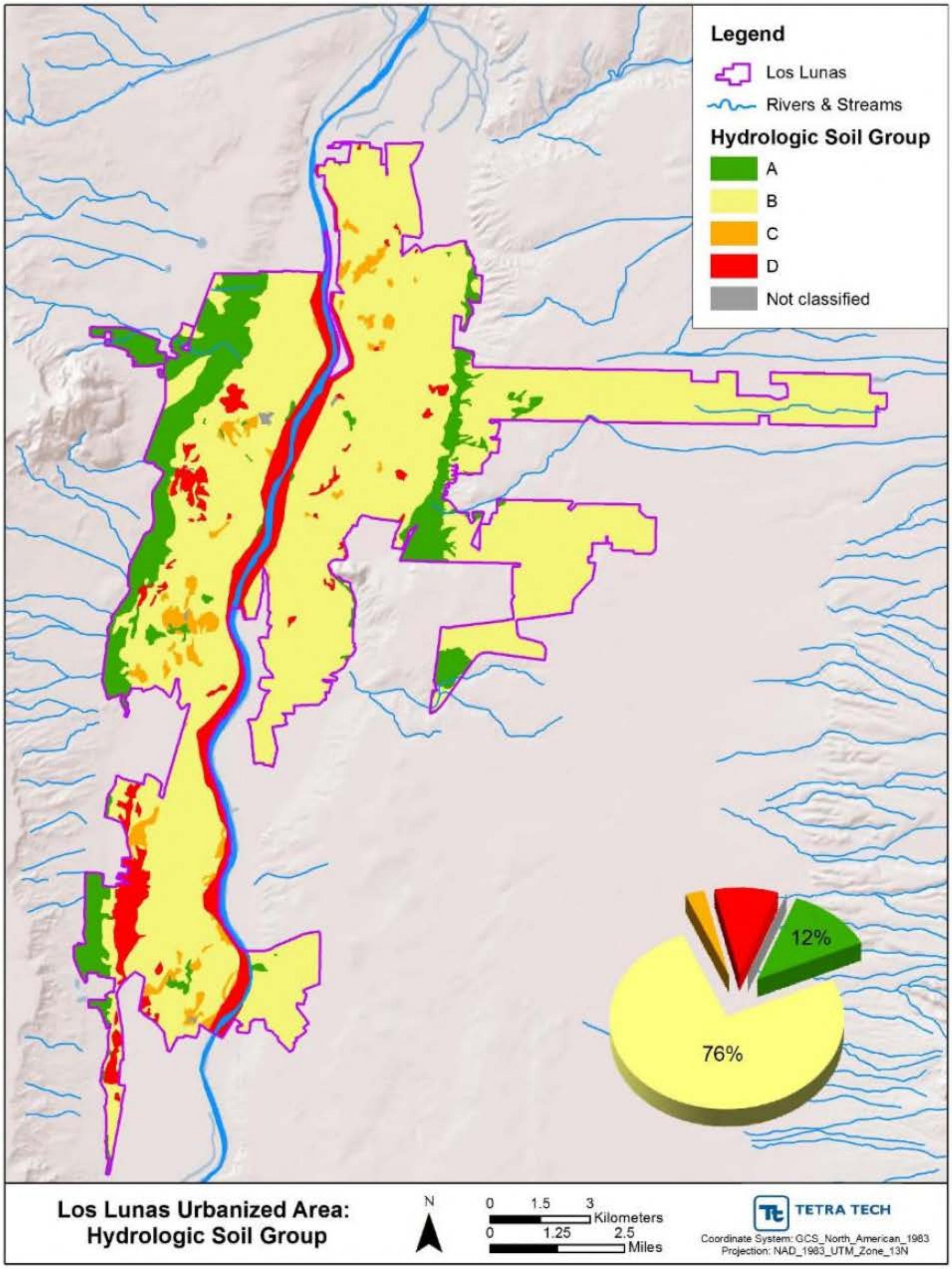

Legend
Farmington
Rivers & Streams
Hydrologic Soil Group
A
B
C
D
Not classified
14%
64%
Farmington Urbanized Area:
Hydrologic Soil Group
N
0 1.25 2.5 Kilometers
0 1 2 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: Albers_Conical_Equal_Area

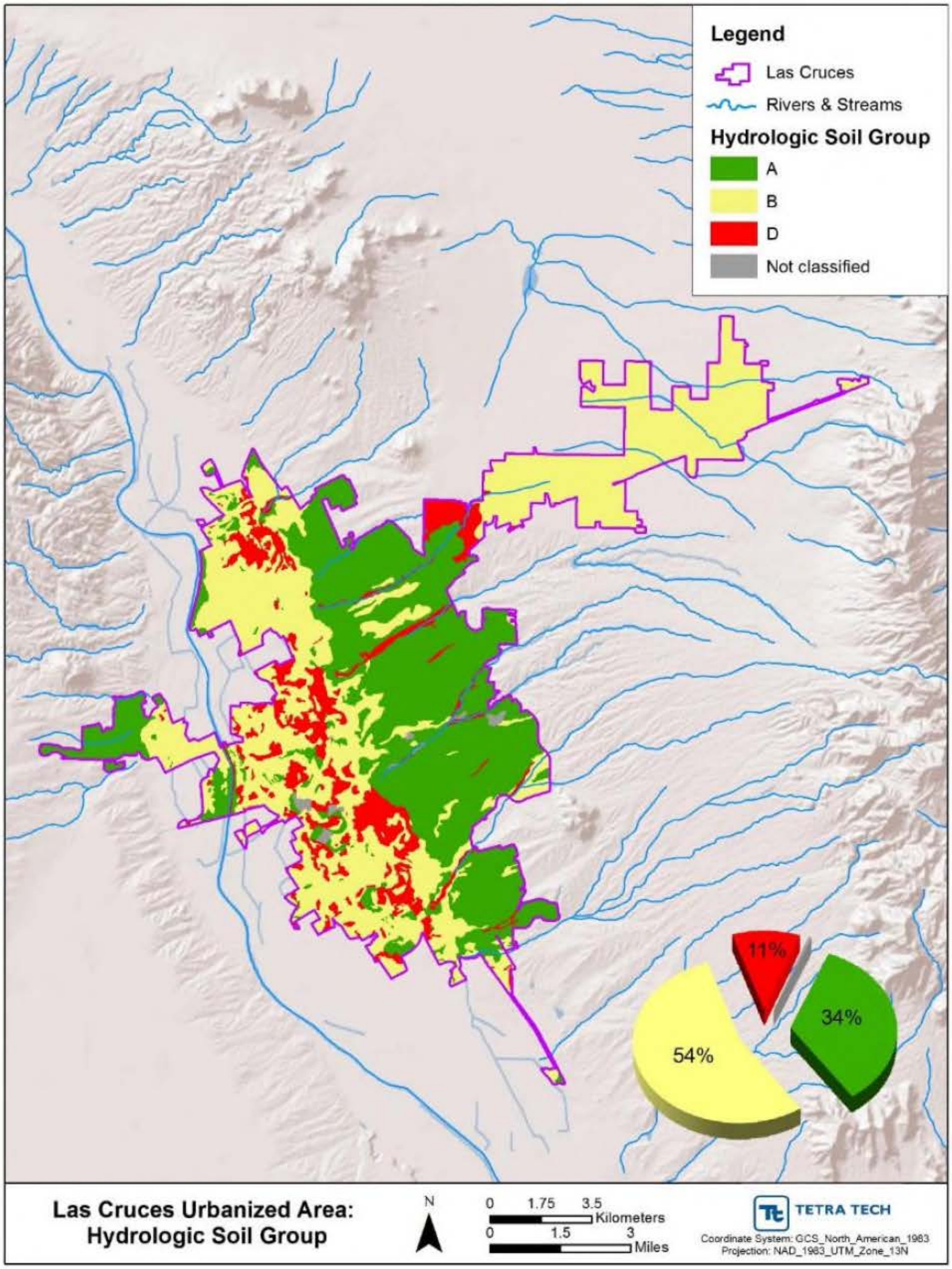

Legend
Santa Fe
Rivers & Streams
Hydrologic Soil Group
A
B
C
D
9%
85%
Santa Fe Urbanized Area:
Hydrologic Soil Group
N
0 1.5 3 Kilometers
0 1.25 2.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N

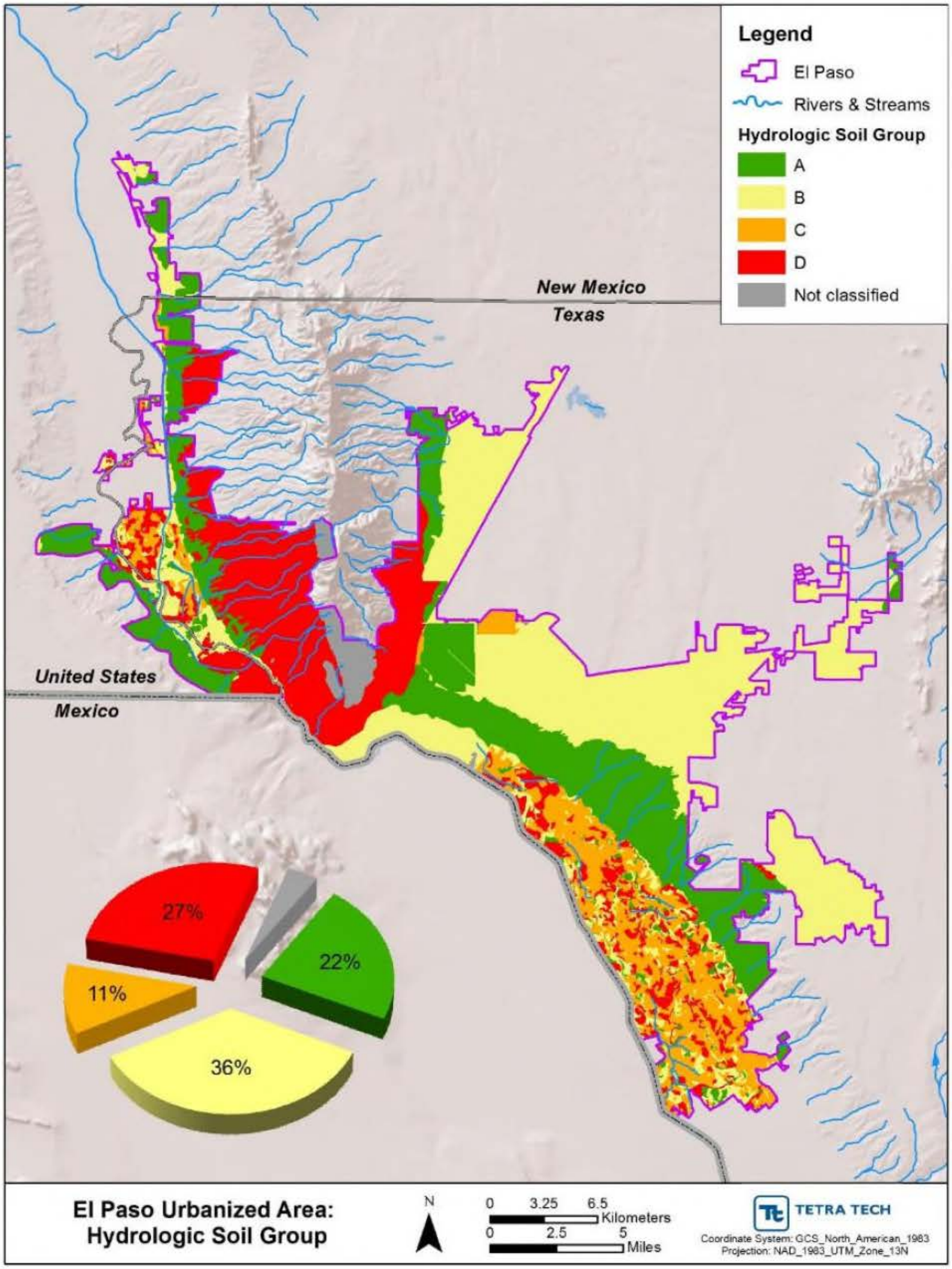


Albuquerque Urbanized Area: Hydrologic Soil Group


Legend
Los Alamos Municipal Boundary
White Rock Municipal Boundary
Los Alamos National Laboratory
Rivers & Streams
Hydrologic Soil Group
A
B
C
D
Not classified
10%
68%
17%
Los Alamos Urban Cluster:
Hydrologic Soil Group
N
0 1 2 Kilometers
0 0.75 1.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N


Legend
Los Lunas
Rivers & Streams
Hydrologic Soil Group
A
B
C
D
Not classified
12%
76%
Los Lunas Urbanized Area:
Hydrologic Soil Group
N
0 1.5 3 Kilometers
0 1.25 2.5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N


Legend
Las Cruces
Rivers & Streams
Hydrologic Soil Group
A
B
D
Not classified
11%
34%
54%
Las Cruces Urbanized Area:
Hydrologic Soil Group
N
0 1.75 3.5 Kilometers
0 1.5 3 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N


Legend
El Paso
Rivers & Streams
Hydrologic Soil Group
A
B
C
D
Not classified
New Mexico
Texas
United States
Mexico
27%
22%
11%
36%
El Paso Urbanized Area:
Hydrologic Soil Group
N
0 3.25 6.5 Kilometers
0 2.5 5 Miles
TETRA TECH
Coordinate System: GCS_North_American_1983
Projection: NAD_1983_UTM_Zone_13N