IEc

Los Alamos National Laboratory Natural Resource Damage Assessment

Review of Available Data on Surface Water Flow and Habitats in Assessment Area Canyons

DOE Contract DE-EM0003939

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Prepared for:

Los Alamos National Laboratory Natural Resource Damage Assessment Trustee Council

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LIST OF EXHIBITS

LIST OF ACRONYMS

°F	degrees Fahrenheit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C.F.R.	Code of Federal Regulations
cfs	cubic feet per second
DAP	Damage Assessment Plan
DEM	Digital Elevation Model
DOE	Department of Energy
DOE-OB	Department of Energy Oversight Bureau
DOI	Department of the Interior
ERU	Ecological Response Units
ESA	Endangered Species Act
HEA	Habitat Equivalency Analysis
IEc	Industrial Economics, Incorporated
ILAP	Integrated Landscape Assessment Project
in	inches
IPCC	The Intergovernmental Panel on Climate Change
LANL	Los Alamos National Laboratory
MRLC	Multi-Resolution Land Characteristics Consortium
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NMDGF	New Mexico Department of Game & Fish
NMED	New Mexico Environment Department
NPS	National Park Service
NRDA	Natural Resource Damage Assessment
PRS	Potential Release Site
RMAP	Regional Riparian Mapping Project
TA	Technical Area
TEUI	Terrestrial Ecological Unit Inventory
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

USGS	United Sates Geological Survey
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

The Los Alamos National Laboratory (LANL) Natural Resource Trustee Council (collectively, the "Trustees") is conducting a natural resource damage assessment (NRDA) related to releases of hazardous substances from operations at LANL.[1] As part of assessment planning efforts, the Trustees finalized a Damage Assessment Plan (DAP) (LANLTC 2014) that describes the activities necessary to complete the NRDA, consistent with the United States Department of the Interior's (DOI) NRDA regulations (43 C.F.R. Part 11) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; 42 U.S.C. Chapter 103). The DAP included several assessment activities related to evaluating natural resource injuries, including the *Review of available data on surface water flow frequency and volume in assessment area canyons* assessment activity. This document serves as the report for this assessment activity and includes a compilation and summary of available information on surface water flows and habitats within the assessment area.[2]

This report provides a framework for characterizing habitats in assessment area canyons and identifying associated biological resources to inform the injury assessment. Specifically, results from this assessment activity will inform the selection and characterization of inputs to Habitat Equivalency Analysis (HEA) models to estimate ecological injuries and scale compensatory restoration.

Surface water flow frequencies and volumes in assessment area canyons are determined based on daily discharge records from the LANL Stream Gauge Network, where available. Outside of LANL, the National Hydrography Dataset (NHD) stream classification is used to understand the flow regimes of canyon streams. Based on these datasets, canyon streams across the assessment area are classified as ephemeral, intermittent, or perennial. Most streams within LANL are classified as ephemeral or intermittent. Generally, canyon streams at higher elevations have more frequent flow. Some areas with intermittent or perennial flow support riparian habitats or wetlands, which have been identified and documented in LANL field surveys.[3] Species that utilize these riparian and wetland areas within LANL are identified and described; and species of potential focus in the NRDA going forward are identified. In addition, information on the general timing for when these species use riparian areas is summarized. The report discusses various sources of habitat information that may be used in conjunction with the NHD stream classification to identify where various flora and fauna may be expected to occur in areas within the spatial scope but where there is less information (i.e., outside of the LANL boundary). Results are synthesized in a series of maps and tables.

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[1] The LANL NRDA Trustee Council includes representatives from the Department of Energy (DOE), United States Department of Agriculture (acting through the Forest Service), Pueblo of Jemez, Pueblo de San Ildefonso, Santa Clara Pueblo, Pueblo de Cochiti, and State of New Mexico (acting through the Office of the Natural Resources Trustee).

[2] This report has been prepared in accordance with the work plan supporting this assessment activity (IEc 2020).

[3] Riparian zones are defined as three-dimensional zones (3-D) of interaction between aquatic and terrestrial ecosystems (Gregory et al. 1991).

CHAPTER 1 | INTRODUCTION

The Los Alamos National Laboratory (LANL) Natural Resource Trustee Council (herein referred to as the "Trustees"), consisting of representatives from the U.S. Department of Energy, U.S. Department of Agriculture acting through the Forest Service, Pueblo of Jemez, Pueblo de San Ildefonso, Santa Clara Pueblo, Pueblo de Cochiti, and the State of New Mexico acting through the Office of the Natural Resources Trustee, are conducting a natural resource damage assessment (NRDA). The NRDA is being implemented following the United States Department of the Interior's (DOI) NRDA regulations (43 C.F.R. Part 11) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; 42 U.S.C. Chapter 103). The goal of the NRDA is to replace, restore, rehabilitate, or acquire the equivalent of injured natural resources and resource services lost due to releases of hazardous substances from LANL operations. The LANL Trustees finalized a Damage Assessment Plan (DAP) in February 2014 (LANLTC 2014). The DAP describes the Trustees' current understanding of the assessment work necessary to complete the NRDA, following the regulatory framework described under 43 C.F.R. Part 11 (LANLTC 2014). Specifically, the DAP describes assessment activities to identify and quantify injuries to natural resources and the services they provide, and to identify, scale, and estimate the costs of restoration actions necessary to compensate the public for these injuries and lost services.[4] One of the assessment activities in the DAP is the *Review of available data on surface water flow, frequency, and volume in assessment area canyons* (LANLTC 2014, p.79).

This assessment activity includes a review and evaluation of available information on surface water (flow, frequency, volume), habitat types, and wildlife in assessment area canyons. Several channel and floodplain habitats within canyons are receptors of LANL contamination and are considered Potential Release Sites (PRSs). To determine and quantify resource losses in the canyons, contaminant concentrations in soil and sediment may be compared to media- and species-specific toxicological thresholds and exposure-response relationships. An understanding of the type of habitat and resources present in the canyons will help determine which media (soil or sediment) and species thresholds or exposure-response relationships may be most appropriate. This report summarizes information related to the types of habitats and biological resources that may be present in canyons and in turn may be exposed to contaminants (see the black outlined box in Exhibit 1-1) by characterizing the flow regimes of canyon streams, documenting the timeframes when stream channel habitats are wet or dry, and compiling information on the biological species that are present in or utilize canyon stream channel and floodplain habitats during wet versus dry conditions. The results of this assessment activity inform the selection and characterization of inputs to a Habitat Equivalency Analysis (HEA) model (e.g., service losses estimated using soil or sediment thresholds) that will be developed as part of a separate injury quantification assessment activity (Exhibit 1-1). The Trustees anticipate using HEA to estimate ecological injuries and

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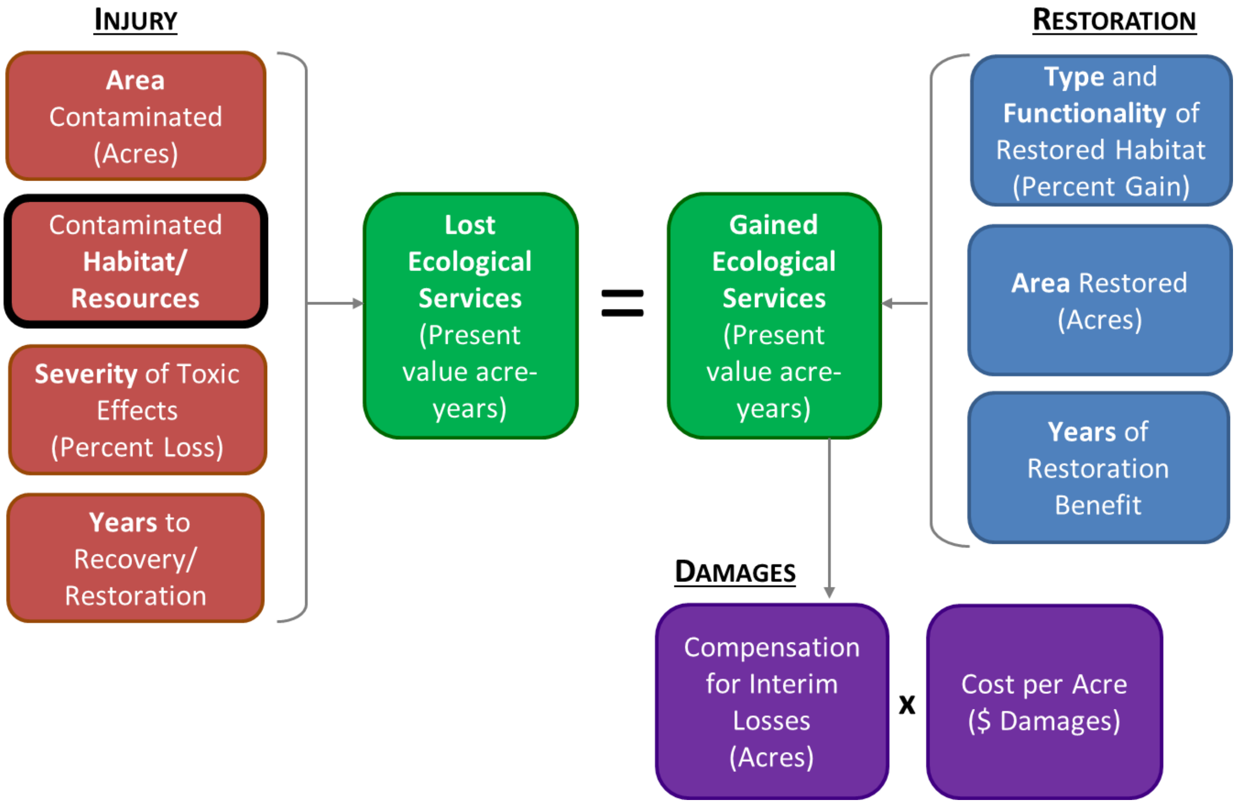
[4] For more information on the NRDA process, refer to the DAP (LANLTC 2014).

develop a quantitative measure of lost services, as well as to determine the type and scale of restoration needed to compensate the public for those injuries (LANLTC 2014).

EXHIBIT 1-1. HABITAT EQUIVALENCY ANALYSIS MODEL



Prior to initiating this assessment activity, Industrial Economics, Incorporated (IEc) prepared a work plan outlining the approaches to implementing the activity (IEc 2020). Consistent with the work plan, the following sections present the goals and objectives of this activity, and summarize the spatial scope and other relevant background information.

1.1 GOALS AND OBJECTIVES

The goals of this assessment activity are:

1. To classify the flow regimes of canyon streams within the spatial scope of this assessment activity as ephemeral, intermittent, or perennial. This includes documenting the timeframes when stream channel habitats are wet or dry; and
2. To compile information on the biological species that are present in or utilize canyon stream channel and floodplain habitats during wet versus dry conditions.

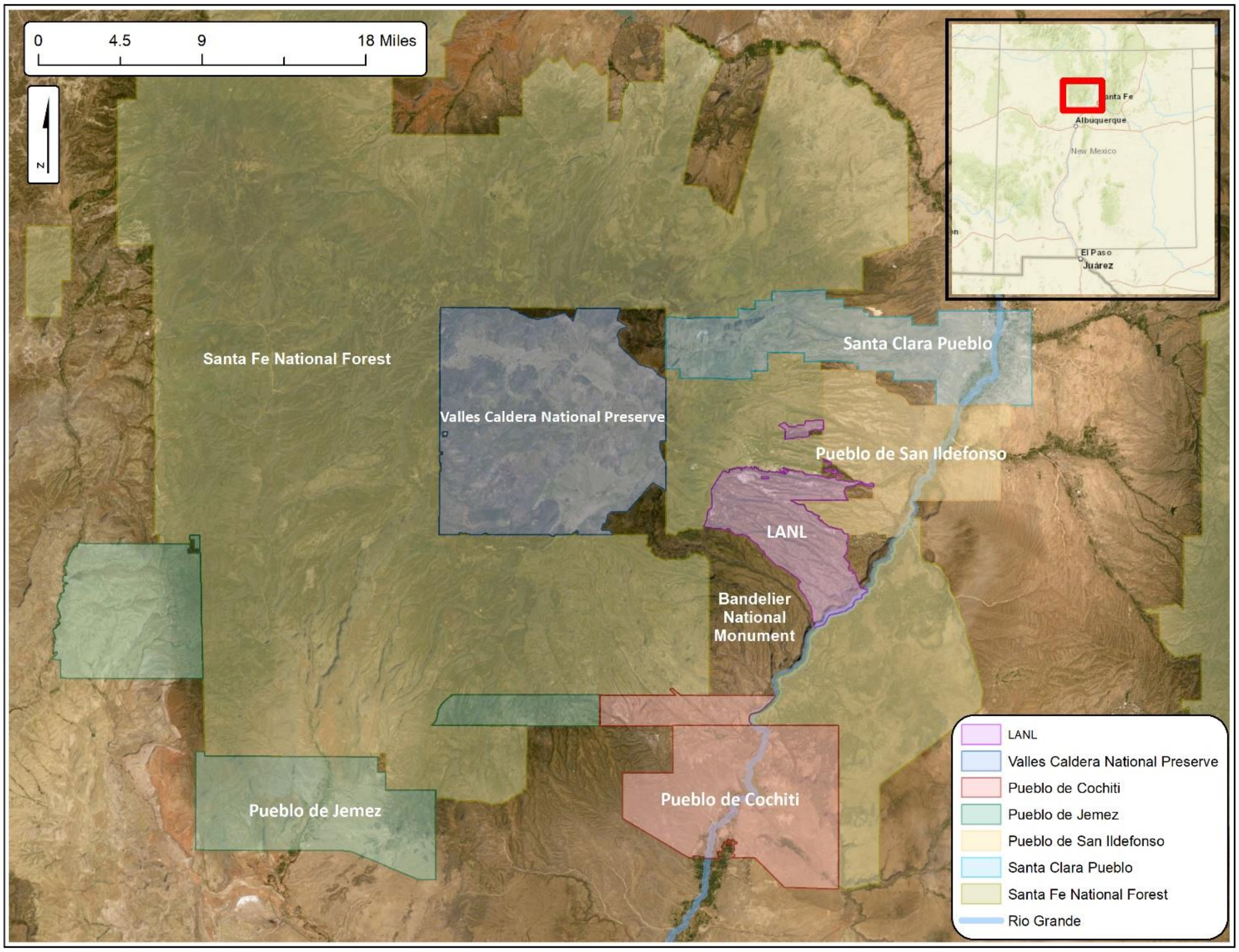
The objectives, which will allow the Trustees to achieve these goals, include compiling and reviewing existing information on:

- Surface water flows in canyons within the spatial scope of this assessment activity, including information on the frequency and volume of flows; and
- Canyon stream channel and floodplain habitats and the biological resources that inhabit or use them, as well as the timing and circumstances of that use.

1.2 SPATIAL SCOPE

The spatial scope of this assessment activity is defined as the canyon stream channels and floodplains that intersect the following lands: LANL, Santa Clara Pueblo, Pueblo de San Ildefonso, Pueblo de Cochiti, Pueblo of Jemez, Santa Fe National Forest, and the Valles Caldera (see Exhibit 1-2).

EXHIBIT 1-2. SPATIAL SCOPE OF THIS ASSESSMENT ACTIVITY



1.3 HYDROLOGIC AREA AND HABITAT CONDITIONS

The presence of surface water is driven primarily by surface runoff from snowmelt and precipitation, as well as discharge from alluvial groundwater systems including springs (LA-UR-04-2714). Another common source of surface water flow within the LANL boundary are outfalls that discharge treated effluent from LANL activities.

The flanks of the Jemez Mountains are characterized by mesa tops bisected by canyons cut by streams. An example of this landscape is the Pajarito Plateau which is marked by canyons that drain the Sierra de los Valles of the Jemez Mountains. Streams are often classified as ephemeral, intermittent, or perennial. Ephemeral streams are dry throughout the year but experience brief periods of surface water flow (i.e., hours to days) in response to precipitation events. Ephemeral streams are usually not sufficiently wet to support riparian vegetation. Intermittent, or seasonal, streams exhibit flow seasonally from spring discharge or due to groundwater contributions and may be supplemented by storm flow. Riparian vegetation can be observed along intermittent streams that have extended periods of flow. Finally, perennial streams flow year-round and support riparian vegetation (Gordon et al. 2004, Levick et al. 2008).

Differences in water availability within canyons result in differences in the suite of species utilizing the habitat. Water supports vegetation growth, which in turn supports microbial and insect communities, and consequently, higher trophic level species. Further, the presence of water may attract a diverse set of biota, in the otherwise arid environment of northern New Mexico.

1.4 OUTLINE FOR THE REMAINDER OF THE REPORT

The remainder of the report is organized as follows:

- **Chapter 2** describes the approach utilized to identify and compile surface water flow and habitat information from available LANL, Pueblo, State, Federal, and other peer-reviewed sources and summarizes the primary data sources relied upon.
- **Chapter 3** describes the surface water flow analysis, calculation of hydrologic parameters (e.g., mean annual flow frequency), stream classification, and identification and review of information on habitats and resident or transient biota from available literature.
- **Chapter 4** summarizes the results of the analysis and presents a synthesis of the identified flow conditions and habitat characteristics.
- **Chapter 5** provides a summary of findings and recommendations.

CHAPTER 2 | DATA AND INFORMATION SOURCES

This chapter describes the approach utilized to identify and compile surface water, habitat, and species characterization data from relevant reports and peer-reviewed literature, and summarizes the key data and information relied upon.

2.1 APPROACH UTILIZED TO IDENTIFY RELEVANT INFORMATION AND KEY DATA SOURCES

2.1.1 SURFACE WATER FLOW DATA

Online searches using Google Scholar, the LANL Electronic Public Reading Room ("LANL Reading Room"), and the online Intellus New Mexico Database[5] ("Intellus") were conducted to identify relevant surface water flow data. Through these searches, State, Pueblo, LANL-specific, and other Federal reports and data sources were identified and reviewed.

Within the LANL boundary, the primary sources of discharge data identified include LANL stream gauge data available through Intellus and Surface Water Data at Los Alamos National Laboratory reports (henceforth "water year reports")[6] from the LANL Reading Room. Outside of the LANL boundary, the United States Geological Survey (USGS) National Water Information System: Web Interface contains real-time data from over 13,500 stations nationwide[7], including four USGS stream gauges near LANL: Rito de los Frijoles near Bandelier National Monument (gauge number 08313350); Bland Canyon near Cochiti, New Mexico (08313400); Santa Clara Creek Near Espanola, New Mexico (08292000); and Jemez River near Jemez, New Mexico (08324000).

In addition to real-time discharge data, the USGS manages the National Hydrography Dataset (NHD), which includes water drainage networks with features such as rivers, streams, and lakes, among others. Additionally, the NHD classifies stream segments as ephemeral, intermittent, or perennial throughout the spatial scope of this assessment activity.[8] These NHD classifications are helpful in classifying streams that are not instrumented with a stream gauge or that otherwise have incomplete flow information.

2.1.2 HABITAT AND SPECIES INFORMATION

Habitat and biological resource information were compiled from gray (i.e., reports and government documents) and peer-reviewed literature. General online searches, Google Scholar searches, and targeted

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[5] Intellus is a publicly accessible database containing environmental data collected by LANL and the Department of Energy Oversight Bureau (DOE-OB). Intellus can be accessed at https://www.intellusnm.com/. Last accessed on December 20th, 2020.

[6] Water years span from October 1st through September 30th. The water year starts in the autumn because some of the precipitation that falls as snow in the late autumn and winter does not exit the system as surface flow until the spring snowmelt. By monitoring flow conditions in water years, the complete water cycle of the system is observed.

[7] The USGS National Water Information System: Web Interface can be accessed at https://waterdata.usgs.gov/nwis. Last accessed on December 20th, 2020.

[8] The NHD classifies stream segments using a modeling approach that incorporates data on elevation, drainage basin, precipitation, and land cover.

searches of the LANL Reading Room were performed using search terms such as “LANL Habitat”, “New Mexico riparian areas” and “LANL species.” Additional searches were conducted through online publication search portals maintained by USGS, the United States Department of Agriculture (USDA) Forest Service, New Mexico Environment Department (NMED), New Mexico Department of Game & Fish (NMDGF), United States Fish and Wildlife Service (USFWS), and the National Park Service (NPS). These searches resulted in the identification and compilation of relevant riparian vegetation surveys, LANL canyon investigation reports, tables of biological species common to the LANL area, and maps of species’ habitat areas.

2.1.3 KEY DATA AND INFORMATION RELIED UPON

The primary sources of information relied upon for this assessment activity are listed below and summarized in more detail in Sections 2.2 and 2.3. The surface water and habitat analyses, utilizing these information sources, are described in Chapter 3.

- **LANL Stream Gauge Network** – consists of 88 stream gauges located throughout the canyons of the Pajarito Plateau and surrounding areas. Daily discharge data from the network were compiled from water year reports and Intellus.
- **USGS National Hydrography Dataset** – updated in March 2021, this dataset provides geospatial information on the drainage networks and stream flow regimes within the spatial scope of this assessment activity.
- **2008-2009 and the 2011 LANL Riparian Inventory** – provides maps of riparian habitat and descriptions of the health of riparian areas in the canyons of the Pajarito Plateau (from field surveys conducted by LANL biologists as part of LANL’s Biological Resources Management Plan).
- **LANL Canyon Investigation Reports** – provides information related to canyon geomorphology, flow frequency, outfall locations, and spring locations, which are used to ground-truth results of the daily discharge data analysis.
- **USDA Forest Service Ecological Response Units (ERU)** – GIS feature class, used as an ecosystem mapping tool for sub-regions of the Southwestern U.S. including northern New Mexico. The feature class includes geospatial information on vegetation types across the spatial scope of this assessment activity. This report displays the 2018 version of this dataset.
- **National Land Cover Database (NLCD)** – serves as the definitive Landsat-based, 30-meter resolution, land cover database for the U.S. The geodatabase provides spatial reference and descriptions of surface characteristics based on thematic classes such as urban, agriculture, and forest, among others. The latest iteration of the dataset is from 2016.

2.2 SUMMARY OF COMPILED SURFACE WATER DATA

This section describes the structure, timeframe, and utility of the identified stream flow (surface water) data.

2.2.1 LANL STREAM GAUGE NETWORK

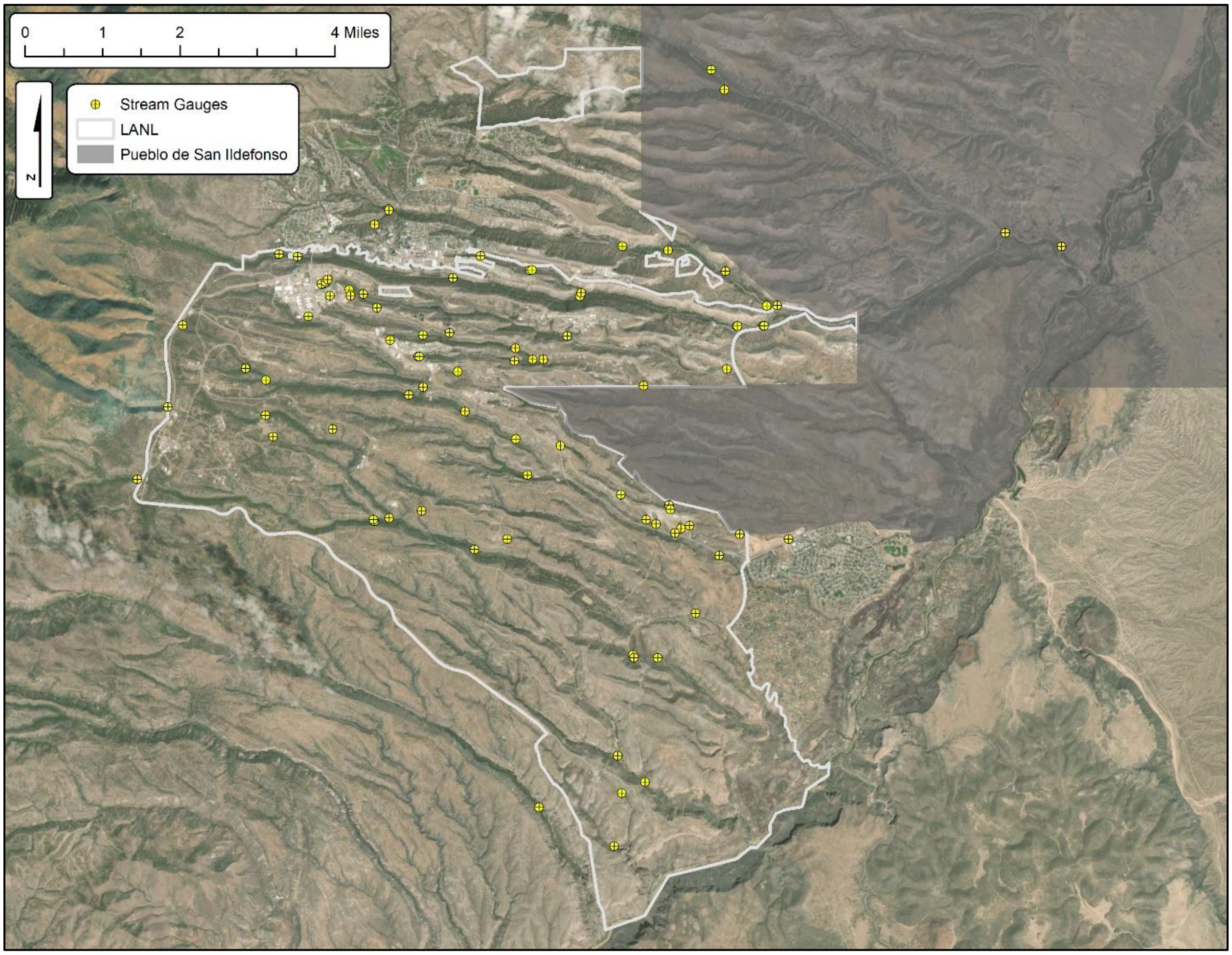
LANL has monitored stream flow in Pajarito Plateau canyons since 1993. The LANL Stream Gauge Network ("LANL gauge network") has evolved over time with the addition of new gauges and the retirement of gauges that experienced malfunctions or were destroyed by post-fire runoff events. For this assessment activity, all years of available data are combined across all stream gauges, which yields a dataset of 88 stream gauges (however, the maximum number of gauges reported in a single year is 73 in water year 2009). Because the network has changed over time, the number of complete years of recorded data varies among gauges (see Appendix A for a table of the LANL gauges and associated information on complete years of data and flow parameters).

LANL stream gauges are named according to the following system (LA-14405-PR):

> *The U.S. Geological Survey (USGS), Water Resources Division, assigns a unique identification number to each stream-gage station it establishes. All sites numbered since 1950 are part of the downstream-order system. The downstream-order system increases station numbers in the downstream direction along main streams, and in the case of this report, their respective mouths to the Rio Grande.*
>
> *This report adheres to the USGS convention of downstream order. Because of the proximity of stations in this network, the first 5 digits of all station numbers are 08313. We have replaced this number string with the letter E in the station number partly to abbreviate and also to accommodate instrumentation.*

Exhibit 2-1 illustrates the spatial distribution of the 88 gauges relied upon for this assessment activity (see Appendix A for a labeled map).

EXHIBIT 2-1. SPATIAL DISTRIBUTION OF THE LANL STREAM GAUGES



The daily discharge data for the LANL gauge network are compiled from two sources: 1) Intellus, and 2) water year reports. Intellus contains peak daily discharge (i.e., maximum daily discharge) data from 2009 through 2017, which are easily obtainable in electronic format. Stream gauge records for years outside of this timeframe are obtained from the water year reports, which are publicly available for the years 1995 through 2014, except for 2001.[9] LANL water year reports indicate that discharge data are based on stage/discharge relationship curves.[10] For water years 1995 through 2011, daily mean discharges are computed based on daily mean gauge height using the curves (or tables with discrete values generated using the curves) and are reported for each day of the water year. In addition, the reports contain estimated values for periods of time when gauges malfunction. Starting in 2012, the water year reports change to reporting daily maximum (or peak) discharge instead of mean daily discharge. Photographs highlighting examples of gauges from various stream classes are provided in Exhibit 2-2, showing

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[9] The report for 2001 is not available in the LANL Reading Room or through online search engines.

[10] Stage refers to the height of the water surface at a location along a stream. Stage-discharge relationships are developed for gauges by physically measuring the flow of the river at a wide range of stages. For each measurement of discharge, there is a corresponding measurement of stage. Subsequent measurements of stage height are converted to discharge using the pre-determined stage-discharge rating curve (USGS 2021).

(clockwise from the top left) E267 in Potrillo Canyon, E040 in Los Alamos Canyon, E350 in Frijoles Canyon, and E262 in Cañon de Valle (LA-UR-12-23350).

EXHIBIT 2-2. EXAMPLES OF LANL STREAM GAUGES

2.2.2 USGS NATIONAL HYDROGRAPHY DATASET

The NHD is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs, and wells. This assessment relies on the NHDFlowline feature class that consists of stream routes that make up a linear surface water drainage network. Each stream section is attributed descriptive information that designates it as a canal/ditch, artificial path, coastline, connector, pipeline, stream/river, or underground conduit. Within the stream/river designation, it further defines segments as intermittent, perennial, or ephemeral based on a modeling approach that incorporates data on elevation, drainage basin, precipitation, and land cover. LANL stream gauge data are limited for Pueblo, Federal, and state lands beyond the LANL boundary, thus the NHD stream classification is useful for characterizing those areas.[11]

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[11] The NHD was updated in March of 2021.

2.3 SUMMARY OF COMPILED HABITAT INFORMATION

This section describes the primary sources of habitat information identified for this assessment activity.

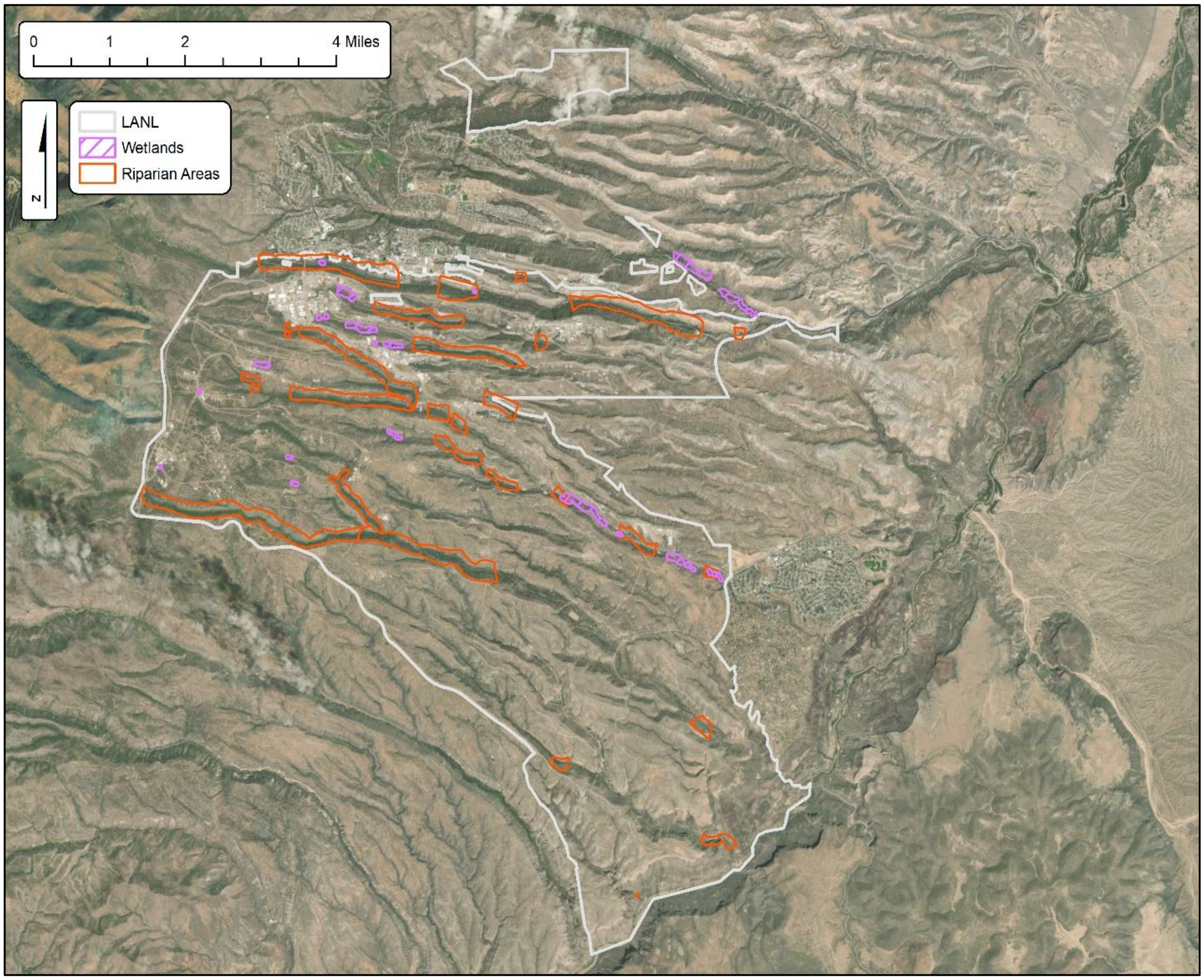
2.3.1 LANL RIPARIAN INVENTORY

The LANL Riparian Inventory is a mapping effort of riparian vegetation along the major canyons of the Pajarito Plateau (LA-UR-11-04768, LA-UR-12-20277). Additionally, the study characterizes riparian habitats, vegetation species distribution, and habitat condition, among other characteristics. The canyons surveyed include:

- Pajarito Canyon
- Two-Mile Canyon (sub-canyon of Pajarito)
- Three-Mile Canyon (sub-canyon of Pajarito)
- Sandia Canyon
- Los Alamos Canyon
- Pueblo Canyon (sub-canyon of Los Alamos)
- DP Canyon (sub-canyon of Los Alamos)
- Ancho Canyon
- Cañon de Valle
- Water Canyon
- Chaquehui Canyon

The field surveys span the elevation gradient of the plateau and identify riparian habitat occurrences from the Rio Grande floodplain to the upper reaches of Pajarito Canyon. IEc digitized the riparian areas surveyed by the LANL Riparian Inventory using ArcMap (Exhibit 2-3).

EXHIBIT 2-3. RIPARIAN AREAS IN LANL (ADAPTED FROM LA-UR-11-04768, LA-UR-12-20277)



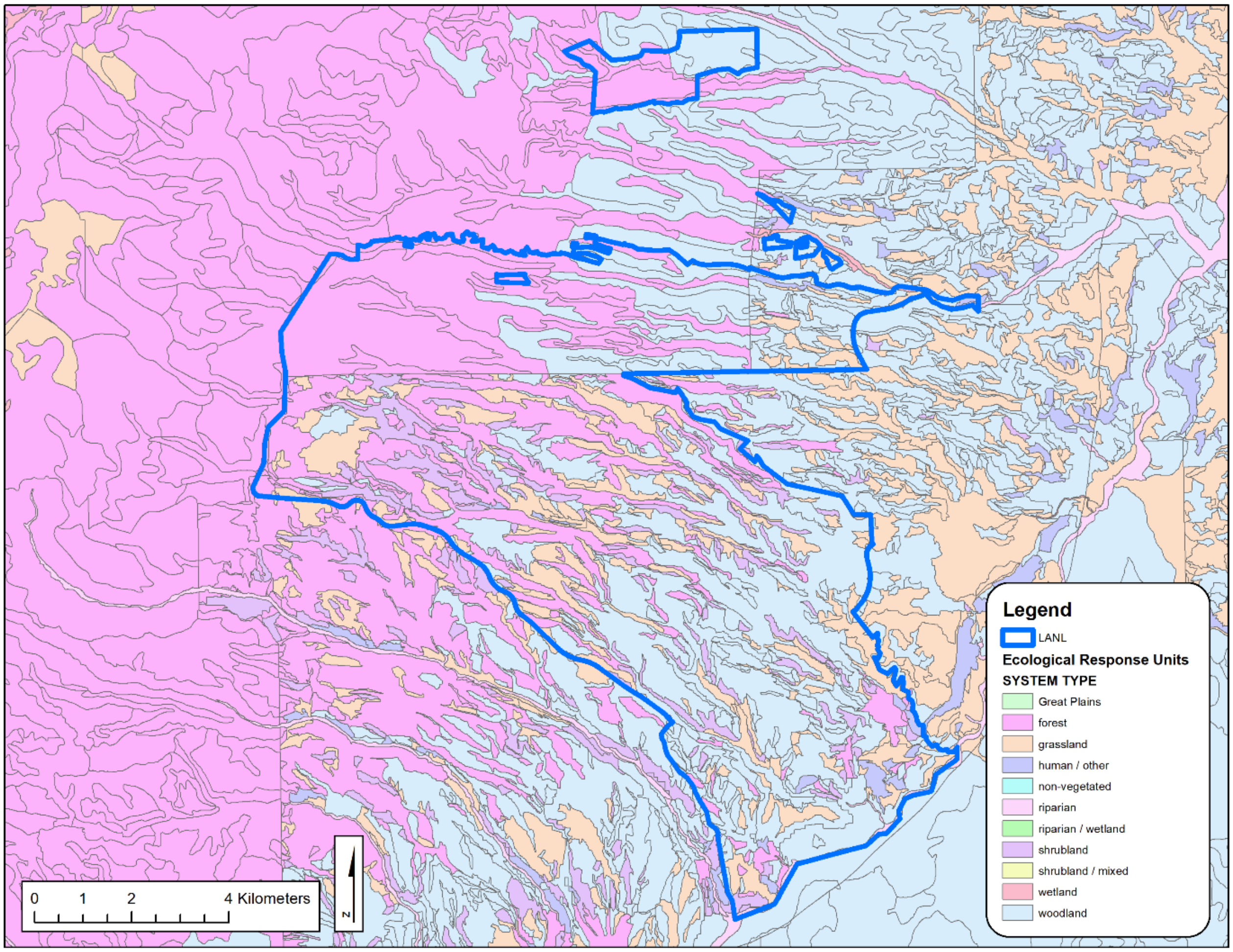
2.3.2 USDA – FOREST SERVICE ECOLOGICAL RESPONSE UNITS

The ERU GIS feature class from the USDA Forest Service provides an extensive ecological map of the area within the spatial scope for this assessment activity. The ERU characterizes areas by vegetative composition (e.g., piñon-juniper woodland). Additionally, vegetated areas are more broadly characterized by "System Type" that includes characterizations such as:

- Forest,
- Woodland,
- Grassland,
- Shrubland,
- Great Plains,
- Riparian, and
- Wetland.

The riparian areas identified in the LANL Riparian Inventory are not characterized as riparian in the ERU (Exhibit 2-4). This is likely because the LANL Riparian Inventory was conducted at a higher resolution than the ERUs. As such, this report relies on the LANL Riparian Inventory to characterize habitats within LANL. In areas outside the scope of the LANL Riparian Inventory, the ERU layer or other habitat data may be used to establish broad habitat conditions.

EXHIBIT 2-4. ECOLOGICAL RESPONSE UNITS IN LANL



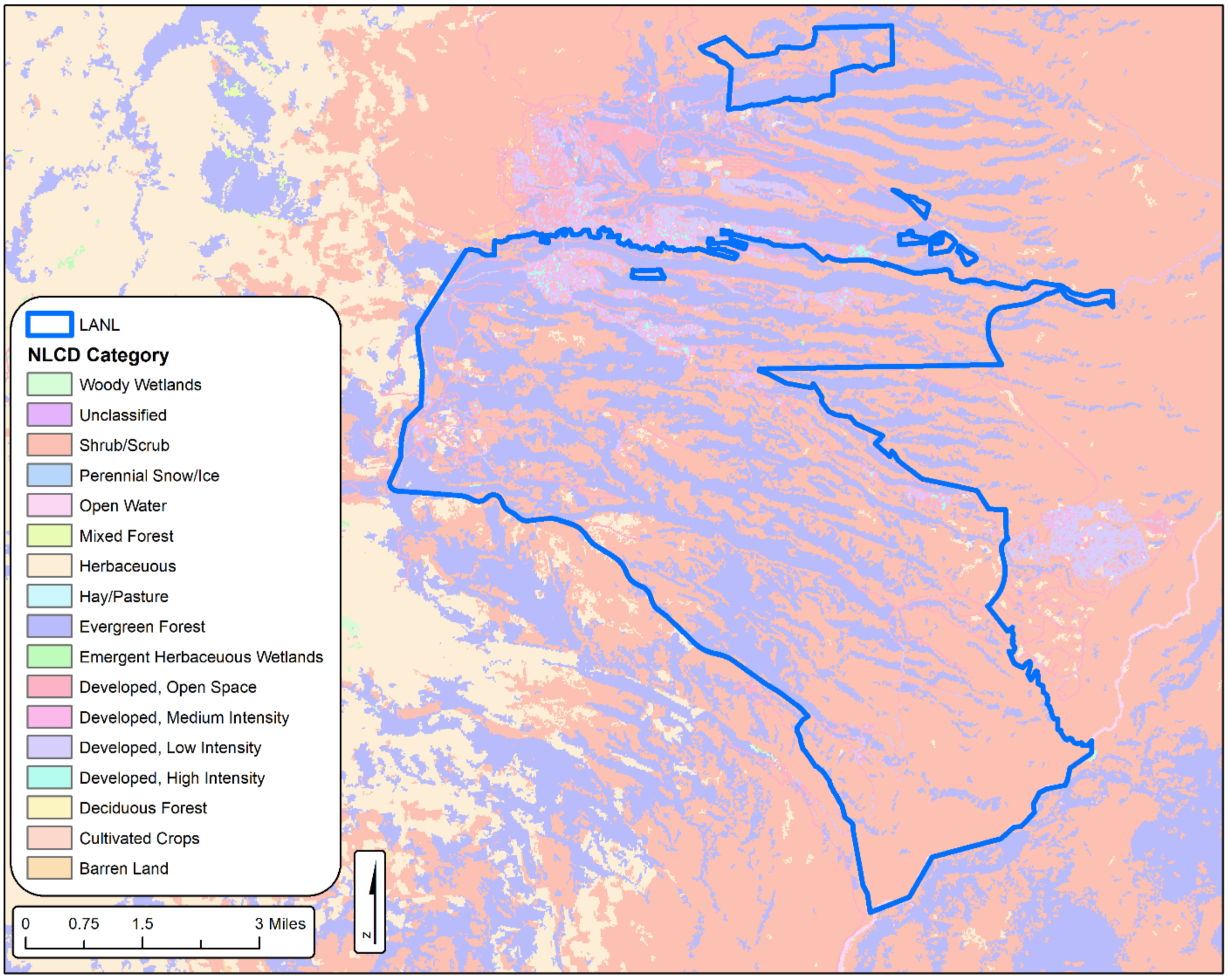
2.3.3 NATIONAL LAND COVER DATABASE

The NLCD is generated by the Multi-Resolution Land Characteristics Consortium (MRLC), a partnership of Federal agencies working together to produce land cover products for all 50 states and Puerto Rico. The NLCD is Landsat-based and includes 30-meter resolution, raster files of landcover classes such as:

- Open Water,
- Developed (Low/Medium/High Intensity),
- Barren Land,
- Deciduous Forest,
- Evergreen Forest,
- Mixed Forest,
- Shrub/Scrub,
- Grassland/Herbaceous, and
- Woody wetlands.

The NLCD is best suited for regional (e.g., northern New Mexico) and national analyses rather than local applications due to its relatively low resolution (USGS 2012). Consequently, the areas classified as wetlands by the NLCD include mostly larger tracts of wet areas, and the NLCD does not capture the level of detail and spatial resolution provided by the LANL Riparian Inventory (Exhibit 2-5). As such, the LANL Riparian Inventory will be used as the primary source of habitat characterization information, but the NLCD may be utilized in areas that lack more detailed information.

EXHIBIT 2-5. NATIONAL LAND COVER DATABASE LANDCOVER CLASSES IN LANL



CHAPTER 3 | SURFACE WATER ANALYSIS AND HABITAT CHARACTERIZATION

This chapter presents climate information to contextualize the analyses (Section 3.1), and summarizes the data analyses used to determine surface water flow frequency in the canyons within the spatial scope (Section 3.2), including the process for calculating hydrologic parameters such as flow frequency per year, flow frequency per season, and maximum daily flow and the approach to delineating canyon stream segments and classifying each segment as ephemeral, intermittent, or perennial. Finally, the habitat and biological resource characterization analysis, which includes a discussion of the vegetation types present in upland and riparian habitats of canyon floodplains and associated wildlife species is presented in Section 3.3.

3.1 CLIMATE CONTEXT

The climate within the spatial scope of this assessment activity is semi-arid with some variability with elevation. In Los Alamos, NM, the mean annual temperature is 50 degrees Fahrenheit (^{o}F) and ranges between 38^{o} and 62^{o} (based on the NOAA climate normals[12] from 1991 through 2020). Mean annual precipitation is approximately 17 inches with 47 percent of the precipitation falling between July and September, corresponding to the monsoon season (NOAA 2021). Northern New Mexico has been experiencing higher temperatures and lower precipitation since the early 1990s and is currently experiencing drought conditions that are likely to persist into the future (LA-UR-17-21060, Dai et al. 2013, Cayan et al. 2010, IPCC 2021). Therefore, against this backdrop of a changing climate at the regional scale, as a preliminary step toward characterizing the flow regimes of LANL canyon streams, the extent to which climatic conditions are static or changing across the temporal scope of the flow records is evaluated (Appendix B). Based on the climate anomalies analysis presented in Appendix B, results show that climatic trends are consistent with drier conditions and higher temperatures becoming more common starting in the early 2000s. The compiled LANL stream gauge data span from 1995 through 2017. Therefore, this assessment relies on surface flow observations before and after the early 2000s when climatic conditions enter a period of higher temperatures and less precipitation known as the 21st century drought (Cayan et al. 2010). The transition begins at the midpoint of the observation window of surface water flow data, suggesting that some of the stream flow observations occurred during a transitional climatic state. However, not all gauges in the LANL gauge network have observations that span from 1990 through 2020. Considering these data limitations, all available data for each stream gauge are used to capture the flow variations at each location despite the influence of climatic variability. Thus, for the analysis on surface flow frequency (Section 3.2.1), all available flow data are combined to generate summary hydrologic parameters such as mean annual flow frequency.

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[12] The World Meteorological Organization (WMO) defines the climate normal as the arithmetic mean of a climate element (e.g., temperature) over a 30-year period (WMO 1989).

3.2 SURFACE WATER ANALYSIS

As noted in Chapter 2, the surface water flow data analysis relies on daily flow data from LANL and USGS. The USGS stream gauge network spans the entire country but only includes four gauges within the spatial scope of this assessment activity. The LANL gauge network is focused on the area within the LANL boundary, offering a denser flow data network. As such, the flow analysis focuses on the LANL gauge network, and relies on the USGS NHD stream class designation for areas that are outside of the LANL gauge network.

Flow data from the LANL gauge network are compiled from water year reports and Intellus. The flow data between these two sources are often overlapping and sometimes inconsistent. After reviewing the water year reports and Intellus daily discharge datasets, IEc determined that the water year reports contain additional data quality information (not contained in Intellus), including 1) data qualifiers for estimated values and 2) information on gauge malfunctions. Therefore, the analysis relies on stream gauge data from the water year reports when both sources have data for a given day. These two datasets are combined for a total of 356,341 daily discharge observations between 1994 through 2017 across the 88 stream gauges.[13]

The following steps are conducted to analyze the compiled surface water flow data, each of which is discussed in greater detail in the sub-sections that follow:

1. Calculate flow statistics for each stream gauge in the LANL gauge network (i.e., frequency of flow by year and by season, and average flow magnitude).
2. Assign stream gauges to appropriate stream segments for visualization and extrapolation purposes.
3. Classify each stream segment as ephemeral, intermittent, or perennial based on the LANL gauge network within LANL and on the NHD stream class where gauges are not present.

3.2.1 CALCULATION OF FLOW PARAMETERS FOR DAILY DISCHARGE DATA

For each of the 88 stream gauges in the LANL gauge network, the following four flow parameters are calculated by water year and season to establish annual and seasonal flow conditions. The calculations for each flow parameter are described in more detail below. See Appendix A for a table presenting these flow parameters for all 88 gauges.

- Mean Annual Flow Frequency (percent),
- Mean Seasonal Flow Frequency (percent),
- Mean Daily Discharge (cubic feet per second, or cfs), and
- Maximum Daily Discharge (cfs).

Approximately 12 percent of reported daily discharge values from water year reports are flagged as estimates, but these estimated values are included in the analysis to capture as much data as possible. The data also indicate that multiple gauges experienced malfunctions (examples listed below). Annual flow parameters are not calculated for gauges with malfunctions within a given year; however seasonal

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[13] The Intellus database was queried in June of 2021 to identify more recent data. Daily discharge observations extending beyond the year 2017 were not identified.

parameters are still calculated for any season that did not have any malfunctions. Example malfunctions include:

- missing data for an unknown or unexplainable reason,
- testing,
- equipment malfunction, and
- decommissioned or inactive due to an event that damaged the stream gauge.

Mean Annual Flow Frequency

To determine the Mean Annual Flow Frequency, the percentage of days that have a daily discharge greater than zero are calculated for each water year for which there is complete discharge data without any reported malfunctions. If there was ice covering the stream (coded in the data as “I”), this is counted as a day with flow because it represents wet conditions. The values are then averaged across all water years for each stream gauge. Mean Annual Flow Frequency for streams across LANL is presented in Exhibit 4-1. However, note that this parameter is not used to define the classification of a given stream segment.

Mean Seasonal Flow Frequency

For Mean Seasonal Flow Frequency, seasons are defined as:

- **Winter:** October through February.
- **Spring Snowmelt:** March through June.
- **Summer Monsoon:** July through September.

For each season of each water year, the percentage of days in that period that had a daily discharge greater than zero or had ice covering the stream are calculated. These values are then averaged across all water years.[14] Mean Seasonal Flow Frequencies are used to define the stream class for a particular stream.

Mean and Maximum Daily Discharge

To calculate Mean and Maximum Daily Discharge, the data for each gauge are averaged across all complete water years. As noted in section 2.2.1, mean daily discharges are reported from 1995 through 2011. Starting in 2012, peak daily discharges are reported instead of mean daily discharge. These two parameters cannot be combined when determining an average flow magnitude. Since flow data before the year 2012 accounts for over 90 percent of the dataset of complete yearly data, only pre-2012 data are used to calculate Mean and Maximum Daily Discharge. Both parameters are presented as summary statistics that offer context but are not used to define the classification of a given stream segment.

3.2.2 STREAM SEGMENT DELINEATION

The 88 gauges in the LANL gauge network represent point locations for which the corresponding data can be spatially extrapolated within the larger stream system of the Pajarito Plateau. To geographically visualize and extrapolate the flow data, the hydrologic attributes of each stream gauge are assigned to the

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[14] A gauge will have some malfunctions in a year but will often have malfunction-free seasons. For this reason, seasonal averages are often based on more years of flow data than annual parameters.

nearest stream segment of the USGS NHDFlowline, and segments are modified as appropriate based on available information.

The NHDFlowline layer is composed of stream segments that extend between tributary confluences. The lengths of the NHD segments within the LANL boundary range from less than 0.01 miles to over 5 miles, depending on specific topography and stream patterns. Long segments occur when there are long sections of stream without any major tributaries. The NHD segmentation pattern is used to extrapolate the flow data from a given stream gauge to the NHD segment to which that gauge corresponds. In some cases, these stream segments are modified to better fit available information regarding on-the-ground conditions (explained in more detail later in this section). Some gauges in the LANL gauge network monitor tributaries that are not identified in the NHDFlowline layer. Most of these gauges are close to PRSs and have been installed to monitor runoff. These gauges, situated on small tributaries near PRSs, generally have very low flow conditions. Because these tributaries are not identified in the NHDFlowline layer, the data associated with gauges on these tributaries are not displayed on maps in Chapter 4. However, flow parameters from these gauges are presented in Appendix A.

Multiple gauges can exist on a given NHD stream segment. This may occur for various reasons, including to capture changes in flow conditions along a stream segment, or because an old gauge was replaced by a new gauge nearby. If there is a cluster of gauges on a given stream segment with similar seasonal flow frequency characteristics (i.e., Mean Seasonal Flow Frequency), the flow parameters described above are averaged across all the gauges within the stream segment. Gauges with more years of data are weighted more heavily than those with fewer years of data, and a weighted average is calculated. Best professional judgement is used to determine whether gauges have similar seasonal flow frequency characteristics, using the difference between the Mean Seasonal Flow Frequency, spatial, and temporal distribution of the multiple gauges.[15]

In cases where the multiple gauges on a single stream segment do not have similar seasonal flow frequency characteristics (again, using the criteria outlined above), the NHD segments are divided into multiple segments. Additional information related to active outfalls, springs, and flow retention structures within the LANL boundary are used to determine where to divide the segments (NMED 2012, LA-UR-16-26788, LA-UR-12-23350). Most flow patterns that are inconsistent within an NHD segment can be explained using this additional information. The location of the outfall, spring, or flow retention structure determines where to end one stream segment and start the next one. For stream segments with multiple gauges displaying disparate flow patterns that are not explained by outfalls, springs, or retention structures, the segments are divided at the midpoint between gauges.

The resulting stream segments are presented in Chapter 4 of this report.

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[15] For example, gauges E252 and E252.5 are on the same NHD stream segment and have Mean Annual Flow Frequency values that differ by 13 percent. However, E252.5 only has a single full year of data, which may be skewing this difference. Instead of applying this one year of data to an individual the stream segment, these two gauges were deemed similar and their flow frequency characteristics were combined on a single segment. In another case, for gauges E121, E122, and E123, all three gauges have almost 100% flow frequency in all seasons. Because they are close together and have similar characteristics, the flow frequency characteristics of these gauges are also averaged for this single stream segment.

3.2.3 STREAM CLASSIFICATION

As described in EPAs *The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest*, "In arid and semi-arid regions, flows have a beginning and an ending in time and space, and there are various classification systems for categorizing the permanency of stream flows, or hydrologic continuum" (Levick et al. 2008). The classifications of perennial, intermittent, and ephemeral are widely used in assessing stream systems. Using this classification system helps extrapolate flow conditions in the LANL stream system to adjacent systems within the spatial scope of this assessment activity.

Levick et al. (2008) define stream categories as:

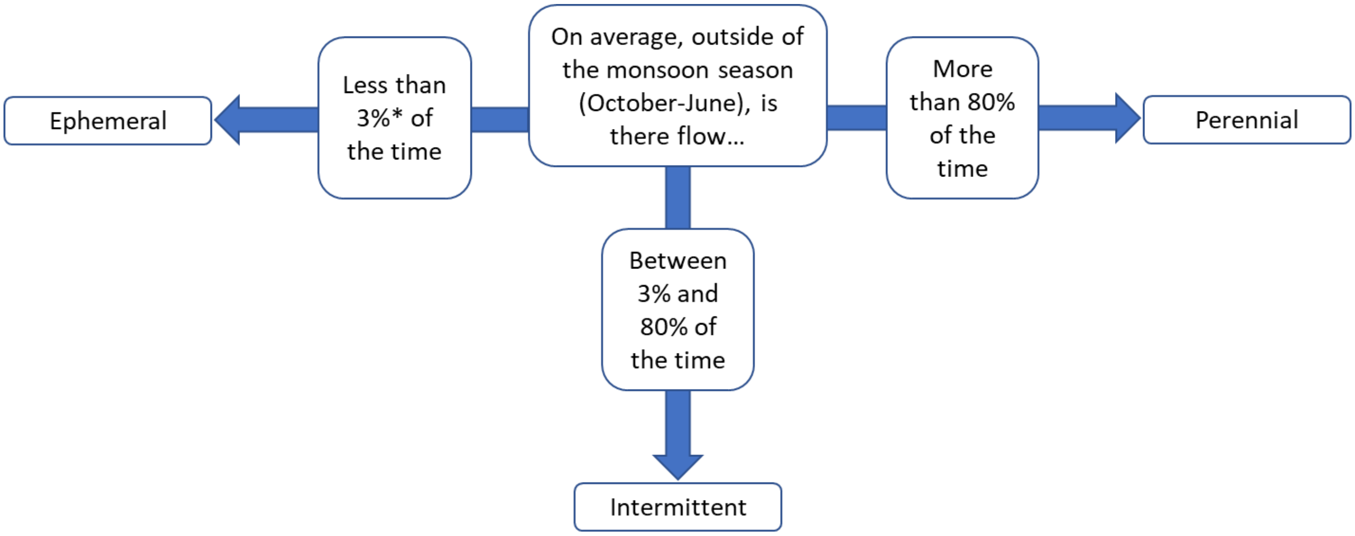
> *Ephemeral: A stream or portion of a stream which flows briefly in direct response to precipitation in the immediate vicinity, and whose channel is at all times above the groundwater reservoir.*
>
> *Intermittent: A stream where portions flow continuously only at certain times of the year, for example when it receives water from a spring, ground-water source or from a surface source, such as melting snow (i.e., seasonal). At low flow there may be dry segments alternating with flowing segments.*
>
> *Perennial: A stream or portion of a stream that flows year-round, is considered a permanent stream, and for which baseflow is maintained by ground-water discharge to the streambed due to the ground-water elevation adjacent to the stream typically being higher than the elevation of the streambed.*

Streams are classified as ephemeral, intermittent, or perennial, using both the LANL stream gauge data and the NHD.

Inside the LANL Gauge Network

Each stream segment within the LANL gauge network is classified as perennial, intermittent, or ephemeral following the classification scheme shown in Exhibit 3-1, which assigns a stream class based on Mean Seasonal Flow Frequency.

EXHIBIT 3-1. STREAM CLASSIFICATION SCHEME FOR LANL GAUGED STREAMS



*3% based on the average number of days outside of the monsoonal season with precipitation greater than 0.5 inches at the Los Alamos weather station (LA-UR-17-21060).

Outside the LANL Gauge Network

For stream sections that are not gauged, the NHD stream classification is used to understand their flow conditions, and, by extension, their probable habitat conditions. The NHD stream classification for all streams within the spatial scope of this assessment activity is presented in Exhibit 4-4.

3.2.4 SURFACE WATER DATA GAPS

This section explains key data gaps identified during the review of available surface water data.

- **Stream Gauge Network**. Beyond the LANL boundary, the number of stream gauges is limited. USGS manages an extensive national stream gauge network (see Chapter 1), but there are only four USGS stream gauges in the vicinity of LANL. Consequently, the NHD stream classification is used to categorize ungauged stream segments throughout the spatial scope.
- **Timeframe of Surface Water Data.** The surface water flow data from the LANL gauge network span from 1994 through 2017. As discussed above, surface water flows have varied over this time and may be influenced by a longer-term cycle of extended drought. Further, gauges from the LANL gauge network were established starting in 1994, and available information on surface water conditions prior to 1994 is limited to qualitative descriptions or observations.

3.3 HABITATS AND SPECIES CHARACTERIZATION

The following section presents a compilation of information related to habitats (upland and riparian) and biological resources (birds, aquatic vertebrates, mammals, benthic macroinvertebrates, and threatened and endangered species) that have been identified primarily in the area around LANL and the Pajarito Plateau. This discussion of wildlife species centers on identifying the most common species within each group and describing how they use upland and riparian habitats. Upland vegetative communities presented in this section align with the descriptions in the ERU and the NLCD habitat sources described in Section 2.3. However, the information presented herein is extracted primarily from field surveys that provide more detailed descriptions of the distribution and composition of the vegetative communities within the spatial scope of this assessment activity. Appendix C provides additional details on the riparian vegetative communities and plant types present in the area.

3.3.1 UPLAND HABITATS

Vegetation distribution in Northern New Mexico is largely dependent on elevation. In the Pajarito Plateau, for example, vegetation adapted to drier areas are generally found at lower elevations while vegetation adapted to higher levels of moisture grow at higher elevations. At the lowest elevations within the spatial scope along the Rio Grande Floodplain (at approximately 5,000 feet), the Plains and Great Basin Riparian - Deciduous forest community is common. This community is characterized by cottonwood and willow, as well as non-native salt cedar and Russian olive (LA-UR-95-2053).

At elevations between 5,600 and 6,200 feet, trees tolerant to dry conditions like one-seed juniper and piñon are common. These species are typical of the Great Basin Conifer woodland community. These two species are also the primary constituents of the eponymous open piñon-juniper woodland found at elevations between 6,200 and 6,900 feet (LA-UR-95-2053).

At higher elevations in the Jemez Mountains, the upland habitat community gradually transitions from Great Basin Conifer Woodland to Rocky Mountain Montane Conifer Forest. Greater precipitation at elevations ranging between 6,900 and 7,500 feet allows ponderosa pine to be more dominant, though it typically occurs with Douglas fir to create a mixed community. However, Douglas fir is more common on north facing slopes. On the edge of the Jemez Mountains at the highest elevations, the community grades to the Rocky Mountain Subalpine Conifer Forest (LA-UR-95-2053).

3.3.2 RIPARIAN HABITATS

Riparian zones can extend from the stream center outwardly to the limits of flooding or can be supported by shallow alluvial groundwater. Additionally, riparian zones extend vertically towards the limit of the canopy. The primary factor determining riparian zone occurrence is the availability of water. Within the spatial scope, riparian areas are scarce but are found downstream from outfalls and springs, and along perennial streams (Exhibit 2-3).

The LANL Riparian Inventory conducted between 2007 and 2011 is the most extensive characterization of riparian habitats within LANL (LA-UR-11-04768, LA-UR-12-20277). The field survey was conducted in nine canyons (see Section 2.3) and spanned lower and upper canyon reaches. At lower elevations, riparian habitats had vegetative communities such as Coyote Willow / Sedge in Pajarito Canyon and Ponderosa Pine – Box Elder / New Mexico Olive – New Mexico Locust Forest in Ancho Canyon. At lower elevations, the riparian vegetation was characterized by small shrubs like narrowleaf cottonwoods and Russian Olive trees. Additionally, the understory was composed of sedges, willows, and grasses. In the case of Ancho and Water Canyons, tree species including ponderosa pine and Box Elder were identified as the primary overstory species in riparian areas. For mid elevation reaches such as Cañada del Buey, the community transitioned to a mixed conifer - shrubland composition and was identified as riparian – mixed conifer / Box Elder – chokecherry forest. Overstory vegetation in these mid-elevation areas was dominated by conifers like Douglas fir and ponderosa pine, while the understory was composed of chokecherry shrubs and cheatgrass. Finally, the upper canyon reaches were characterized by mixed conifer woodlands composed of Gambel oak, ponderosa pine, and Douglas fir. The understory of these higher elevation riparian areas was composed of similar shrubs and grasses found at other canyon reaches.

While understory vegetation in riparian areas was generally composed of similar shrubs, grasses, and willows, with increased elevation a mixed conifer woodland community was typically characteristic of areas with greater water availability. The complete list of vegetative communities and plant species recorded for the LANL Riparian Inventory is provided in Appendix C.

3.3.3 BIRDS

Common bird species at LANL and in the surrounding areas include the western bluebird (*Sialia mexicana*) and the ash-throated flycatcher (*Myiarchus cinerascens*) (LA-UR-19-28950). A 1998 roadside songbird survey conducted by DOE in Los Alamos County primarily detected the spotted towhee (*Psaltriparus maculatus*) and the broad-tailed hummingbird (*Selasphorus platycercu*) (LA-UR-98-4698). A total of five canyons (Cañada del Buey, Water, Los Alamos, Mortandad, and Portillo) and three mesas (TA-70, 33, and 67) were included in the survey. The survey spanned six land cover types and the researchers reported songbird abundances by cover type (Exhibit 3-2). In coniferous cover, the spotted towhee (*Psaltriparus maculatus*) and the Mountain Chickadee (*Parus gambeli*) are the most common species. In grasslands, there is no dominant songbird species, but the common raven (*Corvus corax*) and northern flicker (*Colaptes auratus*) have been identified in these plant communities. Riparian areas are commonly inhabited by the common raven and the broad-tailed hummingbird. Finally, songbird species in shrublands include the broad-tailed hummingbird and the spotted towhee.

EXHIBIT 3-2. SONGBIRD SPECIES IN LANL BY COVER TYPE (LA-UR-98-4698)

COVER TYPE	COMMON NAME	SCIENTIFIC NAME
Ponderosa pine	Spotted towhee	*Psaltriparus maculatus*
	Steller's jay	*Cyanocitta stelleri*
Piñon-juniper Woodland	Spotted towhee	*Psaltriparus maculatus*
	Mountain chickadee	*Parus gambeli*
Mixed-Conifer Forest	Canyon wren	*Catherpes mexicanus*
	Spotted towhee	*Psaltriparus maculatus*
Grasslands	Common raven	*Corvus corax*
	Northern flicker	*Colaptes auritus*
	Say's phoebe	*Sayornis saya*
	Steller's jay	*Cyanocitta stelleri*
	White-breasted nuthatch	*Sitta carolinensis*
Wetland/Riparian	Common raven	*Corvus corax*
	Broad-tailed hummingbird	*Selasphorus platycercus*
	Mountain chickadee	*Parus gambeli*
	Spotted towhee	*Psaltriparus maculatus*
	Yellow-rumped warbler	*Dendroica coronata*
Shrubland	Broad-tailed hummingbird	*Selasphorus platycercus*
	Spotted towhee	*Psaltriparus maculatus*

The songbirds that are common in the wetland/riparian cover type (except the common raven and the mountain chickadee) are found in LANL in the summertime. Arrival to the LANL area is generally in the early spring (around April), and fall migration may persist into October. The common raven and the mountain chickadee are present in the wintertime (LA-12206). Despite surveying multiple canyons and land cover types throughout LANL, the 1998 roadside survey represents only a snapshot of songbird use of riparian habitats. However, as part of the LANL Biological Resources Management Plan, fall songbird migration monitoring has been conducted in the upper end of the Pajarito wetland complex since 2010 (LA-UR-19-23767). In the period between 2010 and 2018, the overall number of bird species captured was variable, but the most common species reported include the lesser goldfinch (*Spinus psaltria*), Wilson's warbler (*Cardellina pusilla*), and the ruby-crowned kinglet (*Regulus calendula*). Similar to the songbirds identified in riparian areas during the 1998 roadside songbird survey, these are migratory songbirds that are present in the LANL area in the early spring and depart in the fall (LA-12206). The variability observed in songbird species present in the area may be attributed to climatic factors. However, there is an incomplete understanding of the environmental variables that influence songbird populations at the Pajarito wetland complex (LA-UR-19-23767). Although the dominant songbird species have not been identified, existing data on the species present are sufficient for the NRDA.

3.3.4 AQUATIC VERTEBRATES

A total of nine fish species have been identified in the Jemez Mountains and as many as 14 species are found in the Rio Grande and Cochiti Reservoir (Lusk and MacRae 2002). There are at least three native fish of the Jemez Mountains: 1) the Rio Grande cutthroat trout, 2) the Rio Grande sucker, and 3) the Rio Grande chub.[16] The preferred stream habitat of the cutthroat is in the upper portions of the Pajarito Plateau. Fish surveys have identified brook trout in stream reaches of the Santa Fe National Forest upstream from LANL. Additionally, rainbow trout has been identified in the stream reaches near the Los Alamos Reservoir (Lusk and MacRae 2002). LANL fish surveys historically have been limited to permanent water bodies in the area including Rito de los Frijoles, Guaje Reservoir, and Los Alamos Reservoir but have not been conducted in recent years (LA-UR-97-4501).[17] Natural migration of fish is prevented in large part by ephemeral stream segments in the spatial scope resulting in geographic isolation for many permanent water bodies that host fish communities (Lusk and MacRae 2002). Consequently, the fish species that are found in the upper portions of the Pajarito Plateau are likely present year-round.

Amphibians in the area around LANL are strongly dependent on riparian habitats for a variety of ecological services including feeding, reproduction, and protective cover, among others. The temporary streams and seasonal ponds characteristic of the Pajarito Plateau are the primary breeding sites and nursery habitats for the spadefoot toad (*Spea multiplicata*), green toad (*Bufo debilis*), red-spotted toad (*Bufo punctatus*), woodhouse toad (*Bufo woodhousii*), canyon treefrog (*Hyla arenicolor*), leopard frog (*Rana pipiens*), and juvenile tiger salamander (*Ambystoma tigrinum*). Seasonal streams or temporary pools are critical for these organisms because immature stages of development (e.g., formation of gills in

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[16] The Rio Grande Chub is listed in the Species of Greatest Conservation Need by the state of New Mexico (NMDGF 2021a).

[17] Guaje and Los Alamos Reservoir were severely impacted by the Cerro Grande Fire of 2000 and the Las Conchas Fire of 2011. After the Cerro Grande Fire, the Los Alamos Reservoir was drained several times and excavated when it was full of sediment in order to retain storage capacity (Reneau et al. 2007). Stocking of fish in the Los Alamos Reservoir was considered unsuitable after the fires and recent fish stocking reports do not list Guaje or Los Alamos Reservoir among the water bodies of the State with hatchery programs (NMDGF 2016, 2021b).

salamanders) are entirely aquatic (Lusk and MacRae 2002). Therefore, amphibians in the area around LANL use riparian areas or temporary pools that are supported by spring snowmelt or precipitation during the July through September monsoon season (LA-13626-MS).

3.3.5 MAMMALS

Twenty-nine species of mammals have been identified in the area around LANL (LA-UR-95-2053). Large mammals identified include mule deer (*Odocoileus Hemionus*), Rocky Mountain elk (*Cervus elaphus nelson*), and coyote (*Canis latrans*) (LA-UR-95-2053, LA-UR-19-28950). These large mammals, particularly mule deer and elk, spend the winter at lower elevations in canyons and mesa tops and move to higher elevations of the Jemez Mountains in warmer months (LA-UR-95-2053). However, they may be present in the spatial scope throughout the year and feed on vegetation in riparian and woodlands areas (Sandoval et al. 2005). Small mammals (e.g., rodents and bats) common in the area include, but are not limited to:

- Spotted bat (*Euderma maculate*),
- Occult little brown bat (*Myotis lucfugus occultus*),
- Pine marten (*Martes americana*), and
- Deer mouse (Peromyscus maniculatus).

Habitats of these small mammals include riparian zones and wetlands (LA-UR-95-2053, LA-UR-97-4501, LA-UR-19-28950). The deer mouse and pine marten may be found in riparian areas while foraging for food, although they are primarily associated with grasslands and forests, respectively (Sullivan 1995). Elevated bat activity in LANL has been reported during the summer months of June through August. This pattern of activity likely coincides with the periods of reproduction (early June) and foraging activity of the young bats (August) (LA-UR-14-20251).

3.3.6 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are small organisms such as worms and emergent aquatic insects that live in aquatic sediment and/or plant and woody material along the bottoms of rivers, streams, and lakes (LA-UR-19-28950). A 2005 study in Los Alamos, Pajarito, and Sandia Canyons identified five taxa of flies and four taxa of worms. Additionally, multiple species of true bugs, beetles, moths, springtails, and seed shrimp were isolated from stream samples collected from these canyons during the study (Exhibit 3-3; LA-14240-SR).

EXHIBIT 3-3. BENTHIC MACROINVERTEBRATES IN LOS ALAMOS, PUEBLO, AND SANDIA CANYONS (LA-14240-SR)

MACROINVERTEBRATE	TAXA NAME	NUMBER OF SPECIES IDENTIFIED
Stonefly	*Plecoptera*	5
Mayfly	*Ephemeroptera*	5
Caddisfly	*Trichoptera*	19
True Fly	*Diptera*	55
Dragon Fly/Damselfly	*Odonata*	4
True Bug	*Hemiptera*	3
Beetle	*Coleoptera*	11
Moth	*Lepidoptera*	1
Springtail	*Poduridae*	1
Segmented Worm	*Annelida*	4
Flatworm	*Platyhelminthes*	1
Pillbug	*Isopoda*	1
Seed Shrimp	*Ostracoda*	1
Gordian Worm	*Nematomorpha*	1
Round Worm	*Nemata*	1

The invertebrate taxa reported in 2005 represent only a snapshot of the macroinvertebrate community because the study was limited to four canyons and sampling was conducted only in the years 2001 and 2002. Additionally, the 2000 Cerro Grande fire burned the upper reaches of the canyons that intersect LANL, impacting invertebrate communities. Vieira et al. (2011) investigated the post-fire effects of stonefly communities in a sub-canyon of Los Alamos and observed that stonefly communities were decimated by increased flooding events. Wildland fires are a natural phenomenon within the spatial scope of this assessment activity. Due to land use changes, fire suppression and climate change, wildland fires are becoming less frequent but at higher intensities. These patterns of wildfires induce greater variability to the baseline conditions of ecosystems and habitats considered for the LANL NRDA[18]. Nonetheless, the list of invertebrates provided in Exhibit 3-3 is useful for understanding the general composition of invertebrates that inhabit the benthic environment of streams. For a more complete list of aquatic invertebrates in the area, refer to the list of species compiled in LA-UR-97-4501.

Benthic macroinvertebrate diversity in LANL has been found to vary significantly between ephemeral-intermittent and perennial streams. Streams that experience non-flow periods (ephemeral and intermittent streams) support benthic macroinvertebrate communities with fewer species and a different species composition than do perennial streams. Prolonged dry conditions tend to favor selected groups of organisms with traits or behavioral strategies for survival through periods of no stream flow. For example, species like *Naididae* (a benthic worm) and *Dasyhelea* (a biting midge fly larvae) have been found in greater abundance in ephemeral-intermittent streams, while *Optioservus* (a type of riffle beetle) and *Nematoda* (a round worm) are more abundant in perennial streams (LA-UR-19-28950). Canyon streams

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[18] The impact of wildland fires on baseline in the context of the LANL NRDA is addressed in a separate report titled *Evaluation of the Impact of Wildland Fires on Pathway, Baseline, and Restoration* (IEc 2021).

in similar settings outside of LANL but within the spatial scope may display similar invertebrate communities according to stream flow patterns.

3.3.7 THREATENED AND ENDANGERED SPECIES

The New Mexico Wildlife Conservation Act lists more than 500 species as threatened or endangered within the spatial scope (NMDGF 2021a). Additionally, the Federal Endangered Species Act (ESA) protects 57 species in New Mexico (U.S. Fish and Wildlife Service 2021). Federally-listed threatened and endangered birds that are known to nest or have been identified during seasonal migration within the spatial scope include the Mexican spotted owl (*Strix occidentalis lucida*), Southwestern willow flycatcher (*Empidonax trailii extimus*), and the Yellow-billed Cuckoo (*Coccyzus americanus*). The American peregrine falcon (*Falco peregrinus anatum*) and the bald eagle (*Haliaeetus leucocephalus*) are formerly federally-listed species that are also present within the spatial scope. (LA-UR-17-29454, LA-UR-98-4698). The Mexican spotted owl generally inhabits mixed conifer ponderosa pine - Gambel oak forests in mountains and canyons (LA-UR-17-29454). The spotted owl’s preferred habitat is the upper elevation canyon reaches (greater than 7,000 feet) of Water, Pajarito, Mortandad, Sandia, and Los Alamos Canyons (Exhibit 3-4). Seasonal movement varies among Mexican spotted owls but they are likely present within their home ranges year-round (LA-UR-17-29454).

The Southwestern willow flycatcher nests along rivers, streams, and wetlands (LA-UR-17-29454). The flycatcher prefers vegetative cover comprised of willows (*Salix spp.*), arroweed (*Pluchea spp.*), buttonbush (*Cephalanthus spp.*), tamarisk (*Tamarix spp.*), and Russian olive[19] (*Eleagnus angustifolia*), among other riparian vegetation. Suitable breeding habitat and foraging areas for the American peregrine falcon exist in the area around LANL and especially in the Jemez Mountains. Southwestern willow flycatchers are present in New Mexico from early May through mid-September and breed from late May through late July. In the winter, these birds migrate to Central and South America (Yong and Finch 1997, Finch and Kelly 1999, USFWS 2002, LA-UR-17-29454). Lastly, the American bald eagle is the only endangered bird species previously mentioned that does not actively nest within the spatial scope or the state of New Mexico. Rather, bald eagles winter along the Rio Grande and congregate downstream from LANL in places like White Rock Canyon and on Cochiti Reservoir. Bald eagles typically roost overnight in tall ponderosa pines in lower portions of tributary canyons (LA-UR-98-4698).

The yellow-billed cuckoo (*Coccyzus americanus*) is a migrant bird species that nest almost exclusively in low-mid elevation riparian/riverine habitats dominated by a cottonwood-willow matrix (LA-UR-17-30912). Survey efforts between 2010 and 2018 have been unsuccessful in identifying the yellow-billed cuckoo within the spatial scope of this assessment (LA-UR-17-30912, LA-UR-19-23767). The migration patterns of the yellow-billed cuckoo are poorly understood but they are known as late spring migrants to Northern New Mexico, and winter in South America from November through April (Halterman et al. 2015, LA-UR-17-30912).

The meadow jumping mouse (see section 3.3.3) is federally-listed as endangered and is endemic to New Mexico. The meadow jumping mouse nests in dry soils but uses streamside riparian/wetland vegetation where it feeds on seeds and insects. The meadow jumping mouse is active only during the growing seasons of grasses and forbs (late spring through September) (Anderson 2008, LA-UR-17-30912).

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[19] Russian olive is listed as a noxious weed in the state of New Mexico. Russian olive grows in riparian areas and displaces native riparian trees like cottonwood and willow (USDA Forest Service 2014).

Sightings of this species are rare in the area and the most recent capture was reported in 2018 along Redondo Creek of the Valles Caldera National Preserve (NMDGF 2021a).

The Jemez Mountains Salamander is one of two endemic plethodontid[20] salamanders that occur at elevations between 6,988 to 11,254 feet in mixed-conifer forest of New Mexico. The Jemez Mountains Salamander does not use standing surface water for any life stage but are common in warm and wet landscapes. Rather, they are terrestrial and are found primarily under rocks, bark, moss mats, and logs. The Jemez Mountains Salamander spends most of its life underground but can be observed at the surface when conditions are warm and wet, primarily from July through September. They feed on invertebrates, ants, mites, and beetles in canyon bottom habitats of the upper Pajarito Plateau (Exhibit 3-4). Very few individuals have been identified in recent surveys; only four individuals were collected between 2010 and 2016 in the area around LANL. The Jemez Mountains Salamander faces various threats including habitat fragmentation from development and habitat destruction by wildfires (LA-UR-17-30912).

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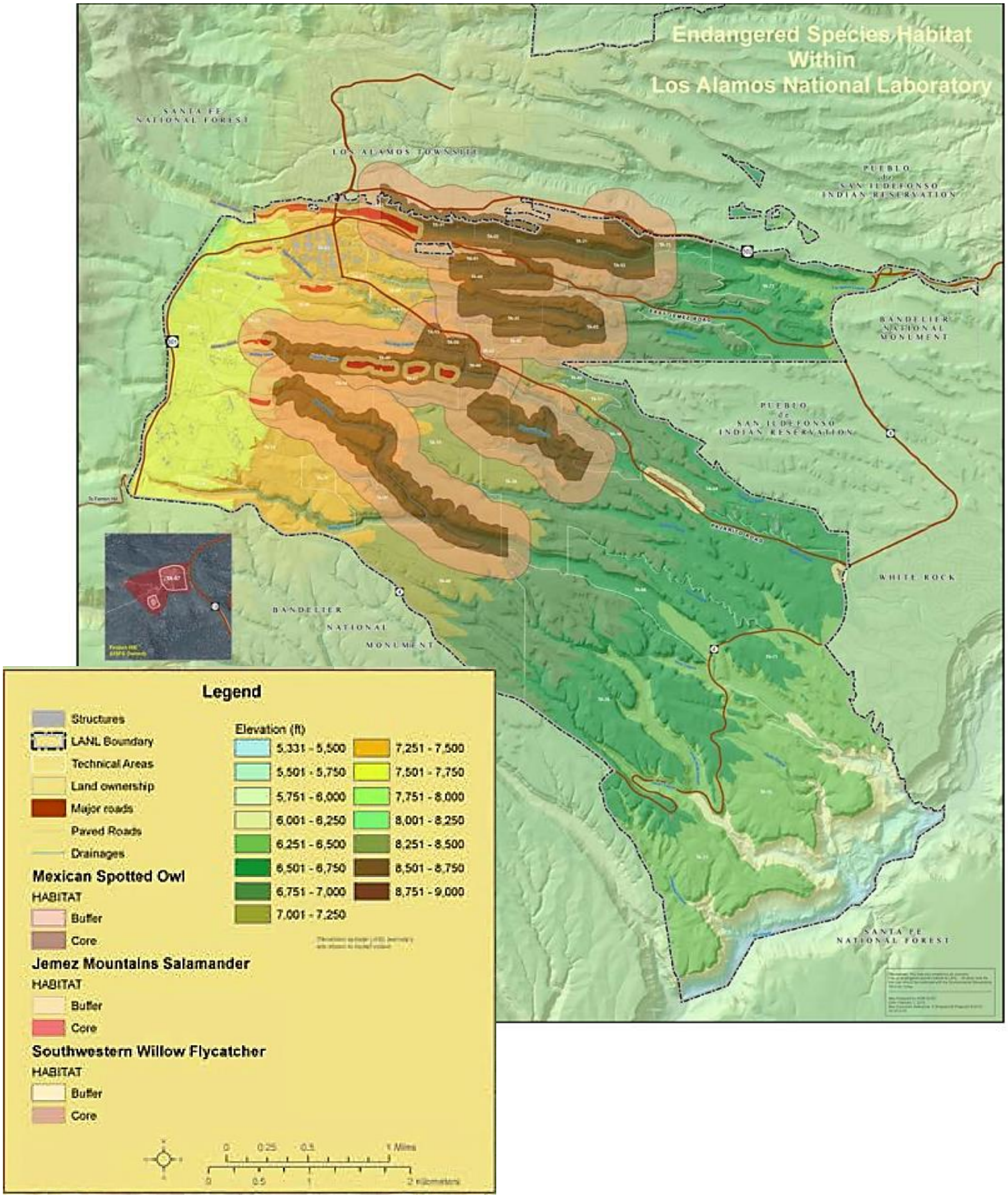
[20] Plethodontidae are a family of lungless salamanders that are abundant in moist forests of North America. Plethodontid salamanders adsorb oxygen directly through their moist skin (LA-UR-17-29454).

EXHIBIT 3-4. HABITAT[21] OF THE MEXICAN SPOTTED OWL, JEMEZ MOUNTAINS SALAMANDER, AND SOUTHWESTERN WILLOW FLYCATCHER AT LANL (FIGURE A-1 OF LA-UR-17-29454)



Note: The legend from Figure A-1 of LA-UR-17-29454 is enlarged on the lower-right corner for clarity.

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[21] Habitats for federally listed threatened and endangered species have been designated as areas of environmental interest (AEI). The AEI has a core and buffer that constitutes areas that are essential for a species and areas protected from undue habitat degradation, respectively (LA-UR-17-29454).

Federally listed invertebrates (including mollusks and amphipods) are not generally present within the spatial scope (U.S. Fish and Wildlife Service 2021a). The endangered Rio Grande Silvery Minnow (*Hybognathus amarus*) was, at one time, one of the most abundant fish species in the Rio Grande, occupying approximately 2,400 miles in New Mexico and Texas to the Gulf of Mexico. Currently, the silvery minnow occurs in the Middle Rio Grande of New Mexico. The species is present through a river stretch of 174 miles that runs from Cochiti Dam to the headwaters of Elephant Butte Reservoir representing only 7 percent of its former range (Magaña 2010).

The threatened and endangered species described above have been the focus of Federal, state, and LANL conservation programs to recover the populations that once existed in the area.

3.3.8 TIMING FOR SPECIES USE OF RIPARIAN AREAS

Exhibit 3-5 presents a summary of when riparian areas are utilized by songbirds, fish, amphibians, mammals and benthic invertebrates. Riparian areas are primarily used during the monsoon season (July through September). Not surprisingly, in the arid landscape at LANL and in the surrounding areas, surface water availability plays a critical role in the use of riparian habitats. From the foraging of insects in riparian areas to critical developmental stages that occur in temporary pools, the availability of surface water during the summer monsoon season is essential for many of the resources described above.

Some species also utilize riparian areas during the spring snowmelt season (March through June). However, this season is often associated with migration or reproduction. The winter season (October through February) represents the season with the lowest likelihood of riparian use because of limited surface water flow. Additionally, migration patterns and hibernation by some species limit their presence in riparian areas during the winter. The summary presented in Exhibit 3-5 is not intended to represent a definitive timeframe of riparian habitat use, but instead, a general indication of the primary seasons for which species, within the spatial scope of this assessment activity, rely on riparian habitats.

EXHIBIT 3-5. SUMMARY OF WHEN RIPARIAN AREAS ARE UTILIZED BY SPECIES GROUP

	WINTER (OCTOBER - FEBRUARY)	SPRING SNOWMELT (MARCH - JUNE)	SUMMER MONSOON (JULY - SEPTEMBER)
Songbirds	□	▨	■
Fish	■	■	■
Amphibians	□	▨	■
Mammals	▨	▨	■
Benthic Invertebrates	▨	■	■

Present	■
Likely to be Present	▨
Unlikely to be Present	□

CHAPTER 4 | RESULTS AND EXTRAPOLATION PROCESS

This chapter presents results for areas within and outside of the LANL gauge network. Flow parameter calculation results for Mean Annual Flow Frequency and stream classification results within the LANL boundary are described in Sections 4.1.1 and 4.1.2, respectively. These results are ground-truthed through a comparison to LANL Canyon Investigation Reports and the LANL Riparian Inventory (Section 4.1.3). A process for extrapolating the available data to areas outside of the LANL gauge network is provided in Section 4.2, for flow conditions (Section 4.2.1) and habitats (Section 4.2.2). Results are presented in maps and tables that may be referenced going forward in the NRDA. Complete hydrologic parameters for the stream gauges considered in this assessment activity are provided in Appendix A.

4.1 LANL STREAM CLASSIFICATIONS

4.1.1 MEAN ANNUAL FLOW

Mean Annual Flow Frequency results for the NHD stream segments in canyons intersecting LANL are illustrated in Exhibit 4-1 (canyon labels are generally north of the canyon they relate to).[22] The results confirm that most canyon streams within LANL do not have flow for the majority of the year, and that stream segments at higher elevations near the headwaters of canyons tend to have more frequent flow (i.e., between 30 and 100 percent Mean Annual Flow Frequency as compared to less than 30 percent for stream segments at mid to lower elevations near the confluence with the Rio Grande). Some exceptions to this pattern include the Rito de los Frijoles stream in the Bandelier National Monument (Frijoles Canyon) and in mid and lower Pueblo Canyon. Rito de los Frijoles is known to have flowing conditions year-round and is also monitored by a USGS stream gauge (08313350) (LA-UR-19-28950). Flows in mid and lower Los Alamos and Pueblo Canyons are largely attributed to LANL outfalls and hydrologic structures such as the Los Alamos Canyon weir in Pueblo Canyon. Flows in the upper canyon reaches are relatively more frequent than mid to lower canyon reaches due to snowmelt runoff and spring discharge and the presence of thin alluvium and a shallow groundwater table. As the streams encounter reaches with thicker alluvium at lower elevations, infiltration to the alluvial groundwater depletes surface water flow (i.e., creates a losing stream) (LA-UR-04-2714).

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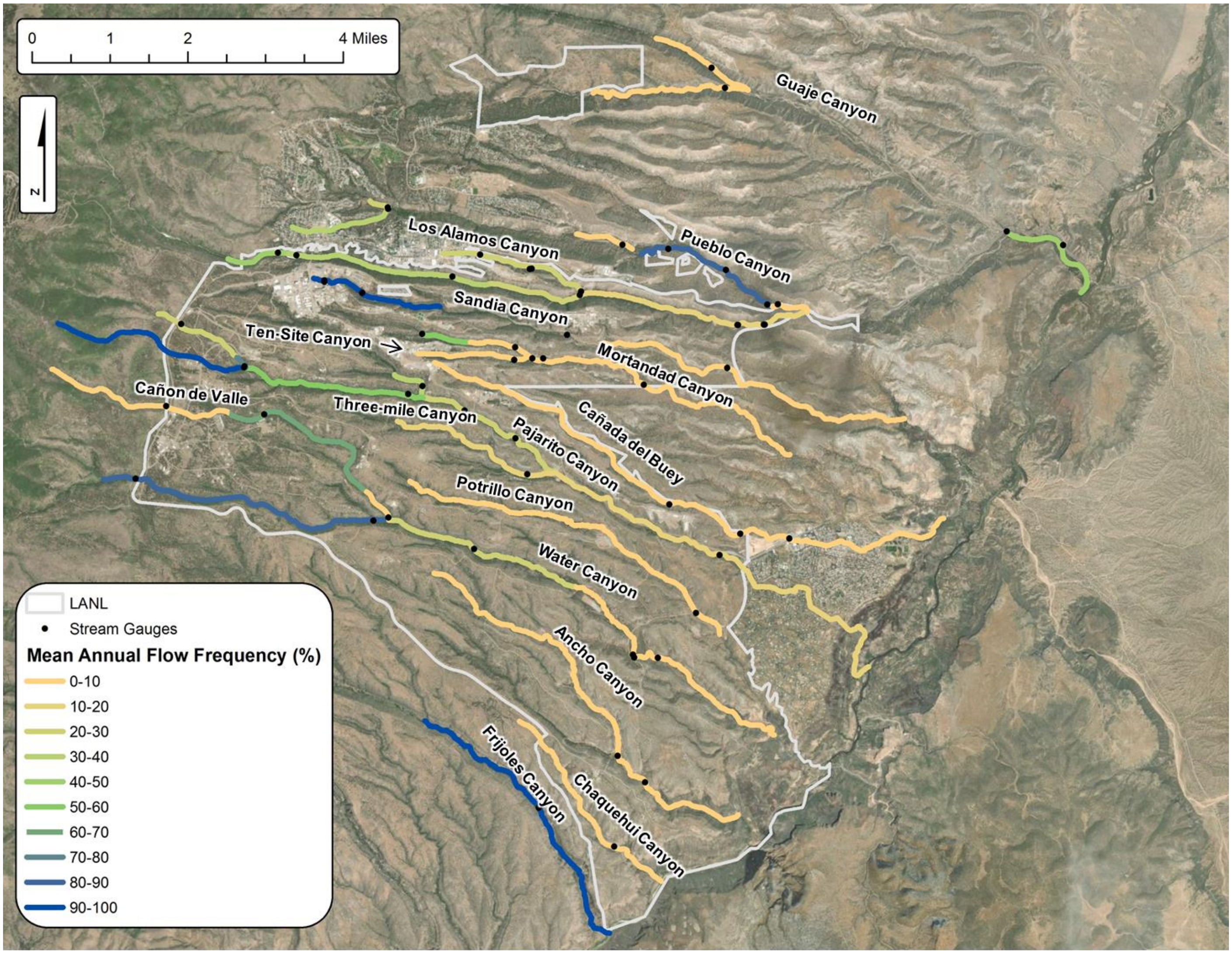
[22] Only gauged stream segments are shown in Exhibit 4-1. For a detailed description of the methodology used to quantify and assign hydrologic parameters to NHD stream segments, refer to Section 3.2.

EXHIBIT 4-1. MEAN ANNUAL FLOW FREQUENCY FOR THE CANYON STREAMS IN LANL

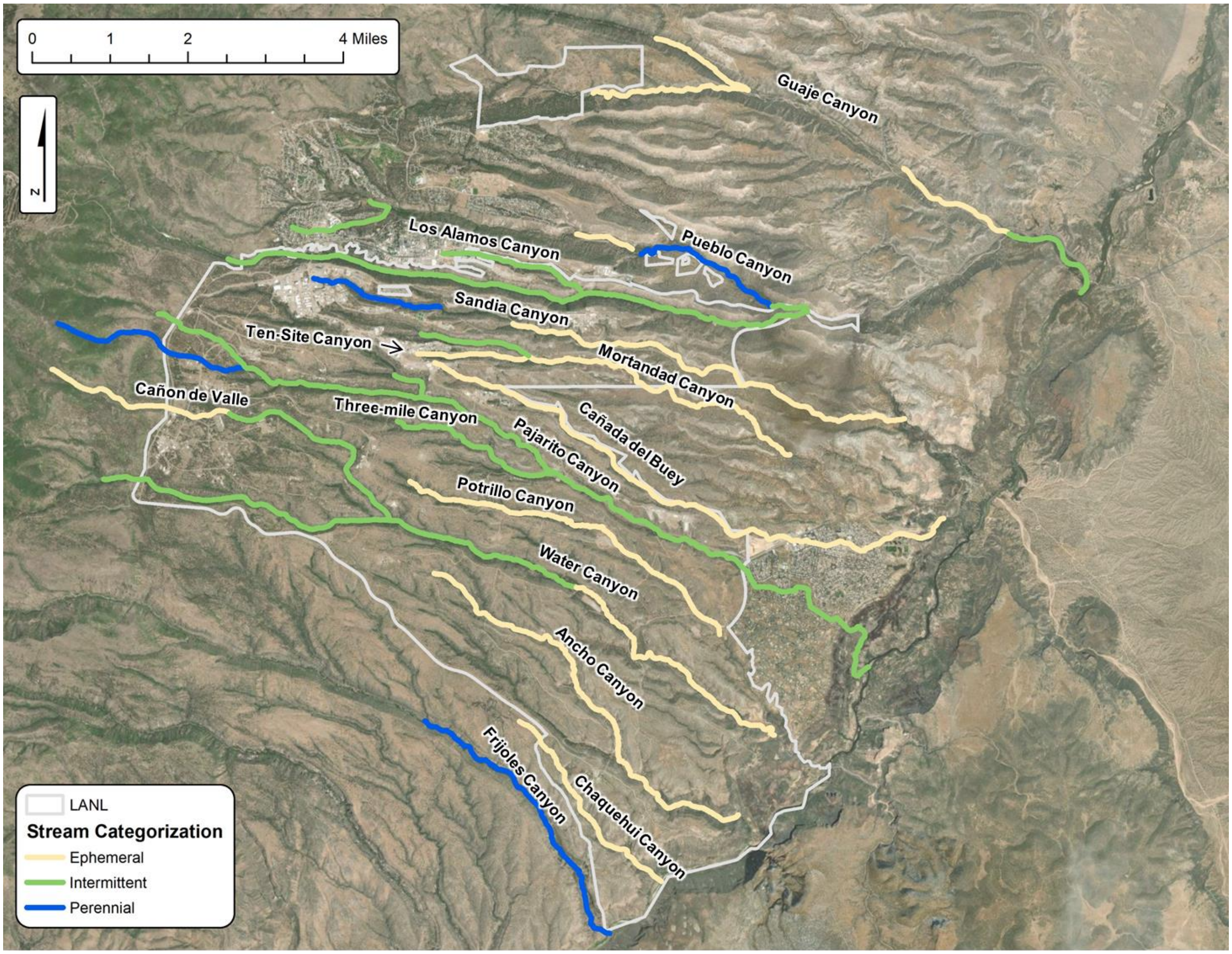


4.1.2 STREAM CLASSIFICATION RESULTS IN LANL

Exhibit 4-2 presents the stream classification results based on Mean Seasonal Flow Frequency and the stream classification method illustrated in Exhibit 3-1 (Section 3.2.3). A comparison of the stream classifications in the NHD for the streams within the LANL boundary and the IEc-derived stream classifications is presented in Figure A-3 in Appendix A. Despite being characterized by a wide range of mean annual flow patterns, Pajarito Canyon and Three-mile Canyon are dominated by stream segments with more frequent flow outside of the summer monsoon season and are therefore characterized by a perennial segment in the upper reaches and intermittent segments downcanyon. Spring discharge in the upper and middle reaches are likely the source of baseflow in this canyon. Water Canyon also exhibits extended stream stretches of intermittent flow in upper segments (Cañon de Valle) and mid canyon segments downstream of the confluence between upper Water Canyon and Cañon de Valle. Similarly, the location of spring discharge in Water Canyon and discharge from LANL outfalls including the TA-16 260

Outfall in Cañon de Valle are likely sources of baseflow in Water Canyon. The remainder of the stream segments shown in Exhibit 4-1 display a predictable stream segment characterization (Exhibit 4-2) in line with observations of Mean Annual Flow Frequency.

EXHIBIT 4-2. STREAM CLASSIFICATION IN LANL



4.1.3 COMPARISON OF THE STREAM CLASSIFICATION TO LANL FIELD-SURVEYS

The LANL Riparian Inventory discussed in Section 3.3.6 was a DOE effort to map riparian areas of LANL canyons. The results of this effort represent the most detailed and accurate assessment of habitat conditions available since they stem from on-the-ground field surveys. The IEc-derived stream classifications, based on LANL gauge data, are intended to support the survey information and fill in gaps where survey data are unavailable.

Surveyed areas generally correspond to stream segments characterized by daily discharge gauge data (Exhibit 4-3). However, not all gauged streams were surveyed for riparian habitat. Specifically, most areas outside of the LANL boundary have not been surveyed. For this reason, intermittent and perennial streams outside of the LANL boundary do not show riparian habitats in Exhibit 4-3. In the areas where the LANL Riparian Inventory and the IEc-derived stream classification overlap, the two datasets are compared. The LANL Canyon Investigation reports serve as an additional source of information to ground truth specific canyon reaches where the IEc-derived stream classification does not corroborate the LANL Riparian Inventory.[23] Although some riparian surveyed areas lack corresponding stream segments (i.e., portions of Ancho Watershed, Cañon de Valle, Water Watershed, Upper Mortandad Canyons, and Upper Pajarito Canyon), riparian and wetland areas are located primarily along stream segments classified as intermittent and perennial, suggesting that the IEc-derived stream classifications are largely in agreement with mapped riparian areas.

When considering information documented in the LANL Riparian Inventory and LANL Canyon Investigation Reports, it is important to acknowledge the wildfire context during which these studies were developed. Wildfires have the potential to significantly affect flow patterns (e.g., increased flow magnitude) and to destroy riparian vegetation due to burning or post-fire increased sedimentation (Pierson et al. 2015). As noted in Section 3.3 of this report, the Cerro Grande (2000) and Las Conchas (2011) fires are the two primary wildfires that have impacted LANL. The Cerro Grande fire is particularly important because it burned several thousand acres within the LANL boundary (LA-UR-01-148). The Las Conchas fire did not significantly burn LANL and did not dramatically alter habitat conditions in LANL. All of the information presented in the LANL Riparian Surveys and Canyon Investigation Reports was published between 2004 through 2011 (i.e., spanning the years after the Cerro Grande fire until immediately after the Las Conchas fire).

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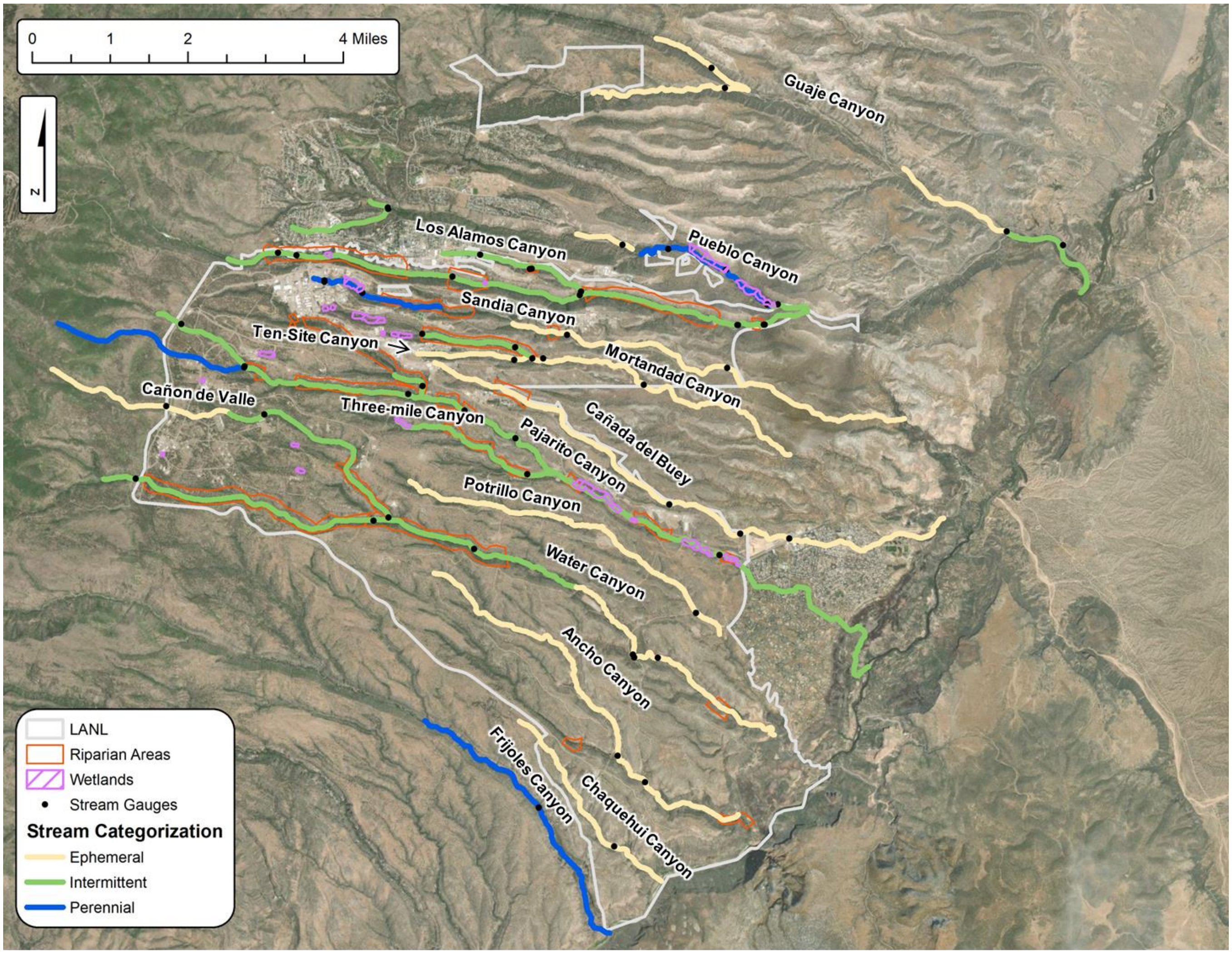
[23] The information relied on for ground-truthing in the LANL Canyon Investigation reports is primarily qualitative including conceptual cross sections of the canyons, and field observations of surface water occurrences.

EXHIBIT 4-3. COMPARISON OF RIPARIAN AREAS AND THE STREAM SEGMENT CLASSIFICATION



Guaje Canyon, the northernmost canyon presented in Exhibit 4-3, is outside of the spatial scope of the LANL Riparian Inventory, limiting a comparison with the stream classification results of this analysis. On the contrary, in Pueblo Canyon[24] the perennial stream segment corresponds with the spatial extent of wetlands surveyed by the LANL Riparian Inventory. In Upper Los Alamos Canyon, the IEc-derived stream class is intermittent, and there are several areas identified as containing riparian habitat. Information related to flow frequency in the Los Alamos Canyon Investigation Report confirm intermittent flow (LA-UR-04-2714). In Sandia Canyon, the surveyed riparian and wetland areas largely correspond with the perennial stream segment shown in Exhibit 4-3. Downcanyon, there is a small riparian area above a stream gauge where the stream classification suggests ephemeral flow. The Sandia Canyon Investigation Report (LA-UR-09-6450) confirms that there is infrequent surface flow starting east of gauge E124, shown on Exhibit 4-3 below the Sandia Canyon label, but also identifies that there is perched alluvial groundwater in this area. This groundwater may support the small riparian area. In

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[24] Pueblo Canyon is a sub-canyon of Los Alamos Canyon watershed.

Mortandad Canyon, riparian habitat occurs on an intermittent stretch of stream. Part of the stream shows low flow conditions (see Exhibit 4-1), although enough flow occurs outside of the summer monsoon season to result in an intermittent classification. The Mortandad Investigation Report (LA-UR-06-6752) confirms that outfalls in upper portions of Mortandad Canyon create intermittent surface water conditions in these areas. Cañada del Buey contains one identified riparian area that is far from any stream gauge. The Cañada del Buey Canyon Investigation Report (LA-UR-09-4668) documents infrequent flow throughout the canyon but identifies perched groundwater near the stream segment shown to support riparian habitat. Pajarito Canyon contains many intermittent stretches and has extensive riparian and wetland habitats that align well with accounts from The Pajarito Canyon Investigation Report (LA-UR-08-5852). Potrillo Canyon does not have documented riparian habitat and has a single stream gauge that suggests ephemeral flow in this area. Water Canyon and Cañon de Valle contain intermittent stream segments that align well with documented riparian areas. The Water Canyon Investigation Report (LA-UR-11-5478) confirms that springs in mid Cañon de Valle contribute to surface water baseflow, and intermittent to ephemeral conditions are downstream of these springs. Additionally, the report notes that Water Canyon Gallery spring, located in upper Water Canyon upstream of the LANL boundary, can create a perennial reach that extends into LANL. As shown in Exhibit 4-1, this area has frequent flow conditions, but it is below the threshold for a perennial stream (flow more than 80 percent of the time). Nevertheless, Exhibit 4-3 shows documented riparian habitat along upper Water Canyon, confirming the frequent flow conditions observed in the discharge data. Ancho and Chaquehui Canyons are classified as ephemeral streams and largely do not support riparian habitats. The Canyon Investigation Report of LA-UR-11-3305, corresponding to Ancho, Chaquehui, and Indio Canyons, identifies a spring at the downstream end of Ancho Canyon before the Rio Grande confluence. This stream segment corresponds to a riparian area in the LANL Riparian Inventory. Finally, Frijoles Canyon contains a perennial stream but is outside of the scope of the LANL Riparian Surveys.

In light of the observed relationship between survey data and the IEc-derived stream classifications, it seems reasonable to assume that stream segments classified as perennial or intermittent via the classification method presented in this report likely support riparian vegetation and may support wetland communities. The available habitat and stream classification information within the LANL boundary are sufficient to develop a reasonably accurate framework for applying habitat-specific (e.g., sediment versus soil) toxicological thresholds for injury assessment purposes, and to identify potentially exposed biological resources.

4.2 EXTRAPOLATION OUTSIDE OF LANL GAUGE NETWORK

As shown above, detailed stream and habitat characterization information are available for canyons within LANL and in limited surrounding areas as a result of the LANL stream gauge network and previous survey efforts. The following section presents the approach for characterizing streams and habitats within the spatial scope of this assessment activity but where limited or less detailed data are available (i.e., outside of LANL).

4.2.1 FLOW CONDITIONS BEYOND THE LANL GAUGE NETWORK

Outside of the LANL gauge network, the NHD is the most comprehensive dataset available related to stream flow conditions. Data from the four USGS stream gauges within the spatial scope confirm the stream classifications in the NHD for the four streams upon which they are situated. Exhibit 4-4 presents the IEc-derived stream classifications for streams within the LANL gauge network and the NHD stream classifications for all other streams. Ultimately, when HEA input parameters are defined for these streams, it may be helpful to reference quantitative information about the specific flow patterns expected in each stream class. Therefore, characteristic hydrographs are presented in Exhibit 4-5 for select stream gauges in Water Year 2007. Two hydrographs are shown for intermittent streams to showcase the variability in seasonality of flow among intermittent streams.

EXHIBIT 4-4. NHD STREAM CLASSIFICATIONS OUTSIDE OF LANL STREAM GAUGE NETWORK

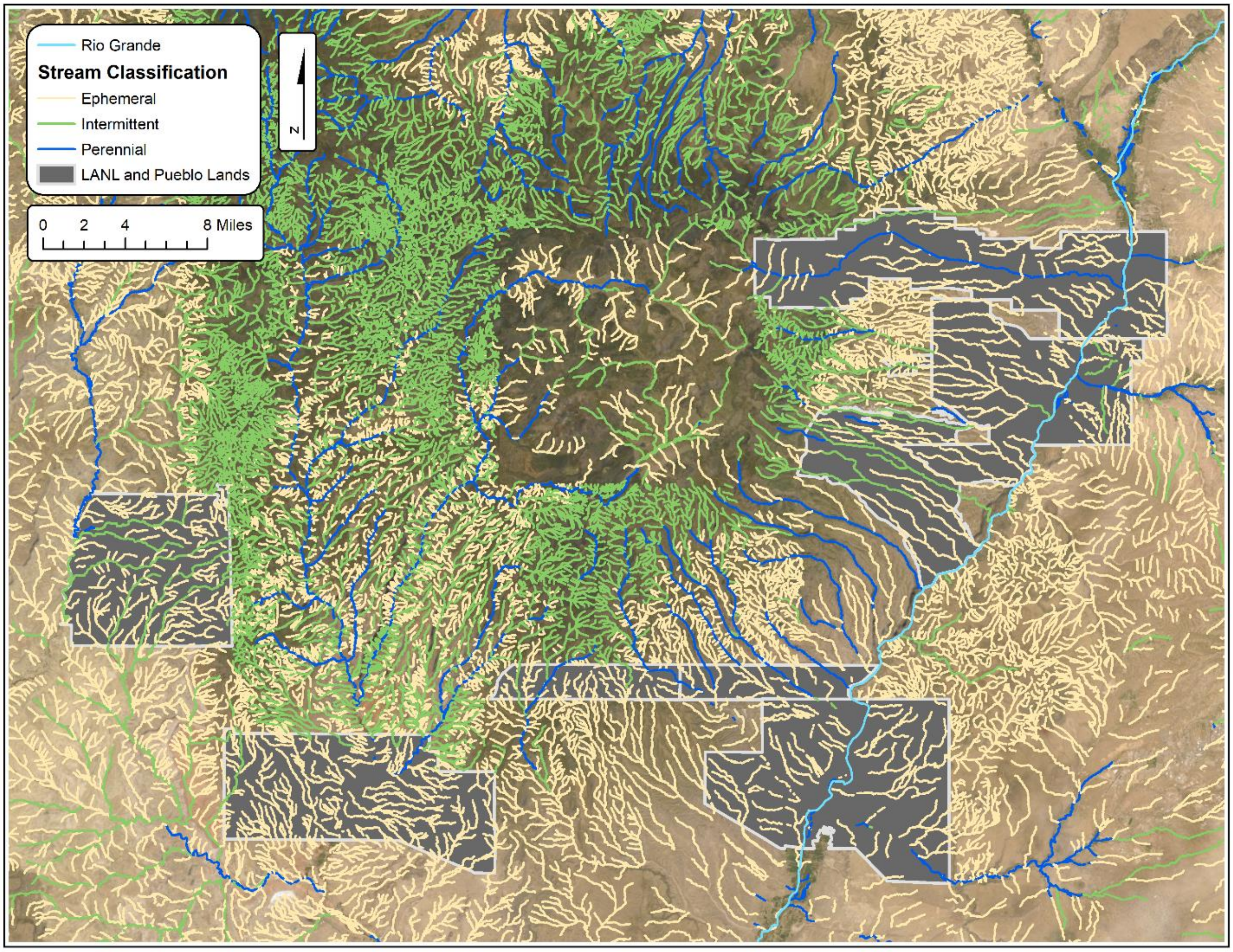
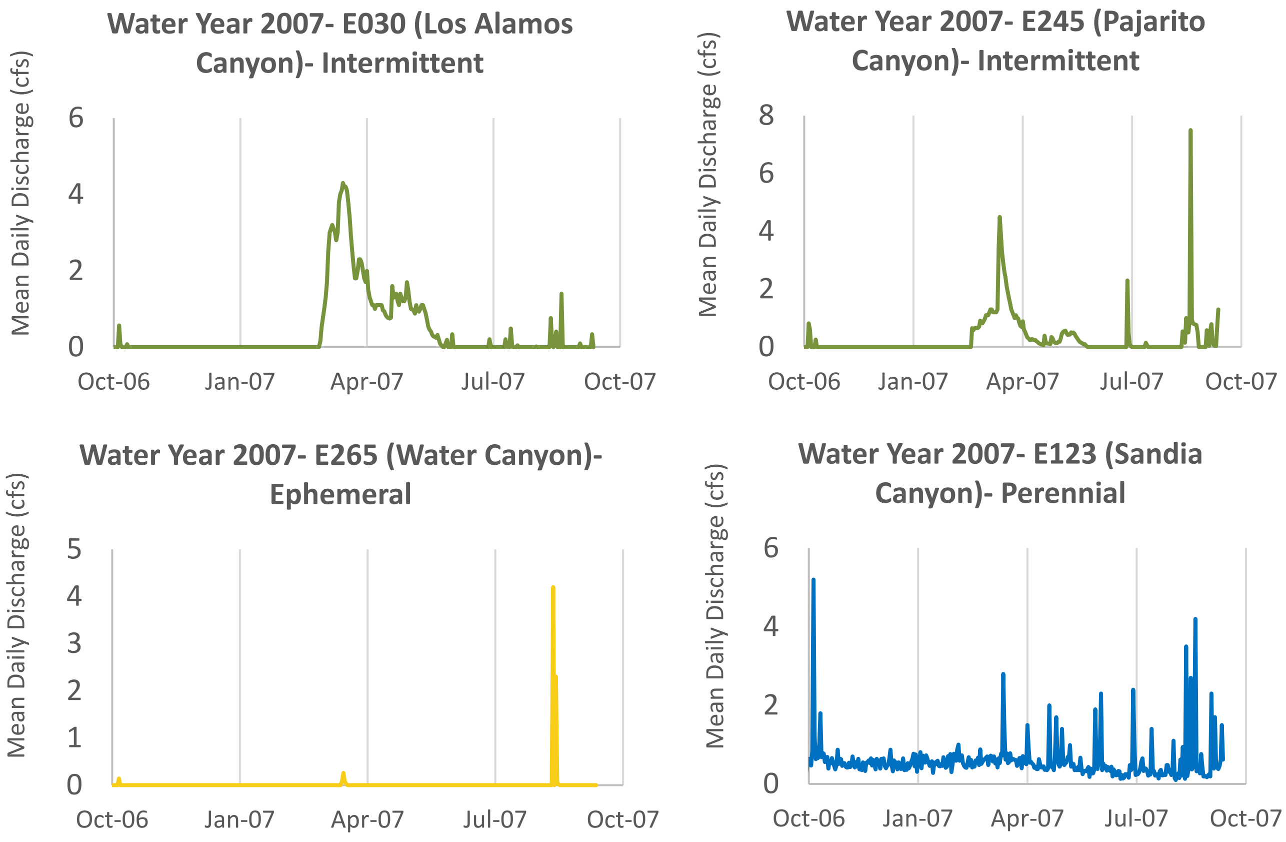


EXHIBIT 4-5. EXAMPLE HYDROGRAPHS FOR EPHEMERAL, INTERMITTENT, AND PERENNIAL STREAMS


Water Year 2007- E030 (Los Alamos Canyon)- Intermittent

Water Year 2007- E245 (Pajarito Canyon)- Intermittent

Water Year 2007- E265 (Water Canyon)- Ephemeral

Water Year 2007- E123 (Sandia Canyon)- Perennial

As illustrated in Exhibit 4-5, intermittent streams have minimal flows in the winter season from October through February, begin to show consistent flowing conditions during spring snowmelt from March through June, and have sporadic flow in response to summer storms. Ephemeral streams show generally low flow, with some days of high flow conditions in response to summer storms. Perennial streams have a base flow year-round and have spikes in flow intermittently throughout the year in response to rain and snowmelt. Since the NHD stream classification does not provide such information on the timing and magnitude of surface water flows, these hydrographs provide insight into the potential flow patterns in streams outside of the LANL boundary.

4.2.2 HABITAT CONDITIONS BEYOND THE LANL HABITAT SURVEYS

Canyon habitats and species are well documented and mapped within the LANL boundary, facilitating the delineation of distinct habitat types, and identification of relevant species for injury quantification. Outside of the LANL boundary, detailed habitat and species information is limited and habitats have not been fully characterized. However, the NLCD and the ERU are spatial datasets that provide regional habitat information that can be combined with the NHD stream class to delineate canyon habitats and identify associated species. This section explores approaches to utilizing these habitat datasets to extrapolate species information from LANL to areas outside of the LANL boundary. The final approach for delineating habitats will be determined during injury quantification.

The NLCD is a Landsat-based, 30-meter resolution, land cover database for the continuous U.S., Hawaii, Alaska, and Puerto Rico (USGS 2012). The Landsat program has collected spectral information through the deployment of multiple satellites that continuously orbit the earth collecting spectral data from the visible to the infrared spectrum. The dataset generates up to 29 landcover classes from processing Landsat imagery, Digital Elevation Models (DEM), estimates of percent imperviousness, and percent tree canopy. The landcover classes include water, high intensity developed, deciduous forest, among others (Homer et al. 2015). The dataset is most accurate when used to support regional and national analysis rather than local applications (USGS 2012). The NLCD habitat classifications presented in Exhibit 4-6 are derived from the 2016 version of the database.

The USDA Forest service developed the ERUs as a framework of ecosystem types for the Southwestern U.S. to facilitate landscape analysis and strategic planning (USDA Forest Service 2014). The ERUs are groupings of vegetation classes that share similar disturbance dynamics, dominant plant species, and theoretical succession sequences. The most recent ERU product relies on forest Terrestrial Ecological Unit Inventory (TEUI) survey data, a collaborative review product with the University of Arizona's Ecologist Jim Malusa, Integrated Landscape Assessment Project (ILAP) data, Regional Riparian Mapping Project (RMAP) data, and subclass information derived from an ILAP grid analysis. The data layers listed are assembled in a hierarchical order starting with previous ERU versions through a series of geoprocessing updates. The highest confidence is placed on TEUI data and RMAP data, with these sources weighted more heavily. The ERUs presented in Exhibit 4-7 are derived from a 2018 publication of the feature class.

Refer to Section 2.3 for a comparison of the two datasets. Additionally, Appendix D presents maps of the habitat datasets for some of the LANL Trustee lands.

EXHIBIT 4-6. NATIONAL LAND COVER DATABASE HABITAT CLASSIFICATIONS

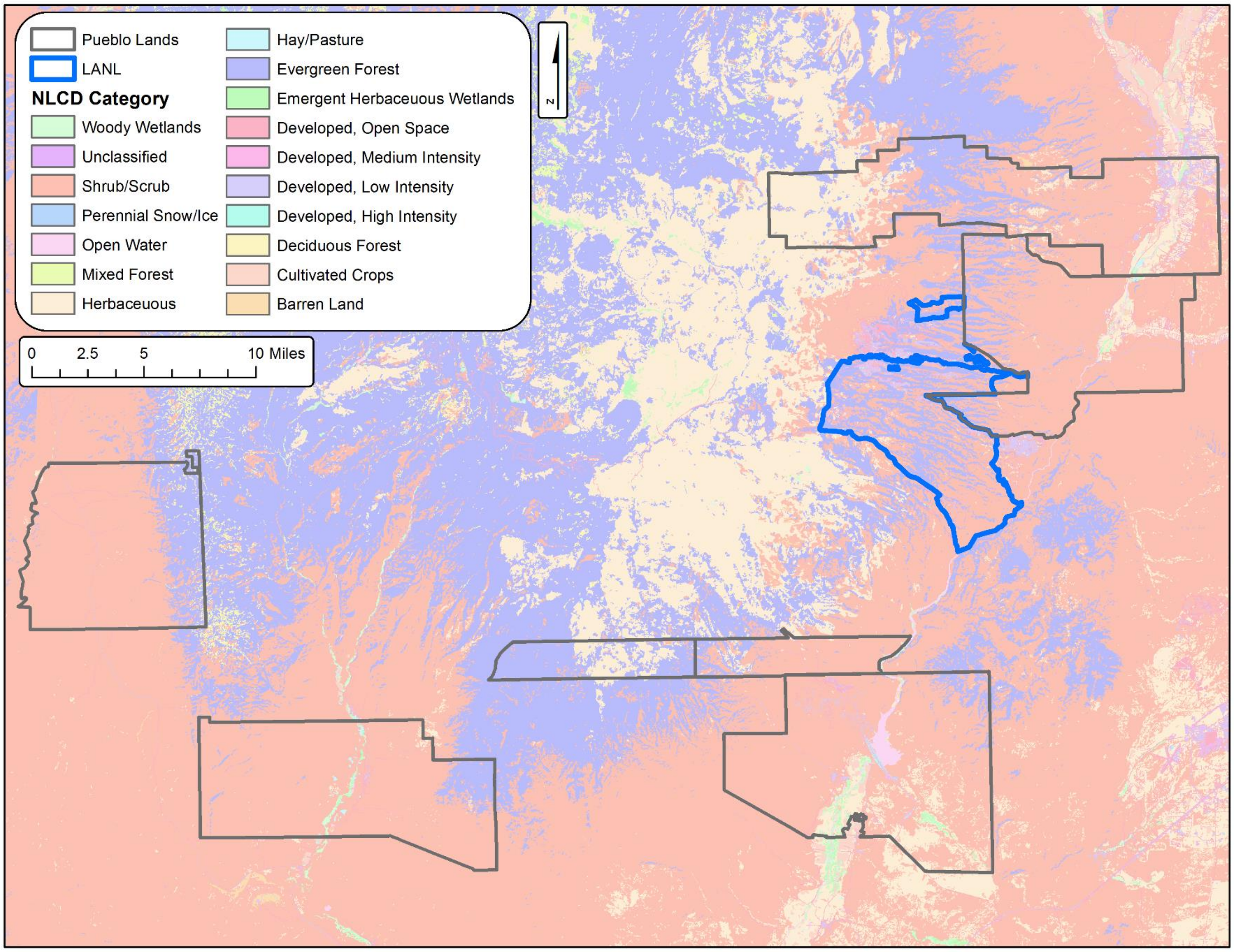
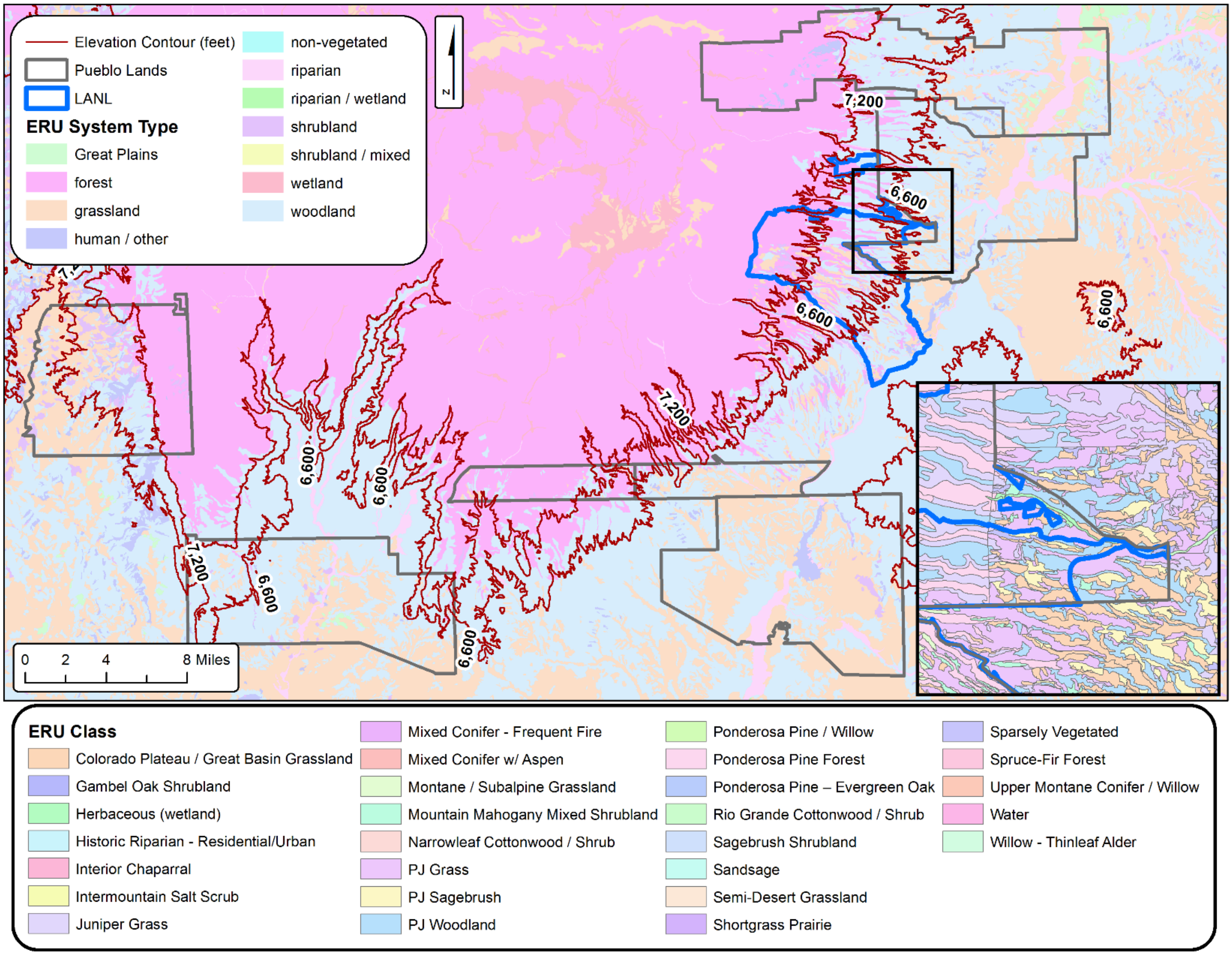


EXHIBIT 4-7. ECOLOGICAL RESPONSE UNIT SYSTEM TYPE AND CLASS DESIGNATIONS



As shown in Exhibit 4-7, the ERU feature class presents an ERU System Type and the ERU Class. These vegetation categories represent different levels of information. The ERU System Type is a general category, while the ERU Class is more specific. For example, the ERU Class of piñon-juniper woodland (PJ woodland) is associated with the ERU System Type of woodland. For injury quantification purposes, the ERU System Type, in conjunction with the NHD stream class, may be sufficient to delineate distinct habitats outside of the LANL boundary, and the more specific ERU Class may not be needed. Another approach to delineating habitats outside of the LANL boundary is to rely on elevation zones to identify general habitat groupings. For example, instead of separating all grasslands from woodlands and woodlands from forests using the ERU System Type, elevation zones that contain a mixture of grasslands and woodlands may be grouped and associated with the same species. An example of these elevation zones is displayed in Exhibit 4-7.

Regardless of the approach to identifying and grouping habitats, detailed information about species that utilize different habitats within the LANL boundaries may be extrapolated to similar habitat types outside of the LANL boundary, as appropriate for injury quantification.

CHAPTER 5 | SUMMARY AND RECOMMENDATIONS

5.1 SUMMARY

In this assessment activity, surface water and habitat information are compiled, synthesized, and analyzed to establish an understanding of stream classifications, habitat conditions, and associated biological species in areas where data are available. A discussion of alternative data sources, such as national surface water and habitat datasets, is presented for areas where detailed data are unavailable. The following sections summarize IEc's recommendations for designating streams as ephemeral, intermittent, and perennial and how to apply these classifications. Additionally, this chapter presents recommendations for species of particular interest to target during injury quantification.

5.2 RECOMMENDATIONS

As mentioned in the introduction, HEA offers a quantitative framework to estimate ecological injuries and scale restoration. The following sections describe how the stream habitat compilation and analysis effort will inform the selection of HEA approaches and inputs during injury quantification.

5.2.1 HABITAT AND THRESHOLD DESIGNATIONS

Since abiotic contaminant data (i.e., soil, sediment, surface water) are often collected as part of remedial efforts, NRDA injury analyses typically utilize environmental media-specific, contaminant concentration-based thresholds to identify injuries to natural resources and quantify service losses. Understanding which habitats, environmental media, and natural resources are present and, by extension, potentially exposed to hazardous substances, helps determine which thresholds and exposure-response relationships are most relevant. For example, toxicity testing and thresholds developed based on that testing are typically conducted separately for sediment-, water-, and soil-associated biota. Thus, understanding which of these media are present within canyon-bottom habitats, and when such habitats may be considered wet versus dry, is key to applying appropriate thresholds. Exhibit 5-1 outlines IEc's recommendations for categorizing assessment area streams with regard to habitat and substrate.

EXHIBIT 5-1. HABITAT AND THRESHOLD DESIGNATION FOR STREAMS

	HABITAT AND SUBSTRATE DESIGNATION	
STREAM CLASSIFICATION	**STREAMS OUTSIDE OF LANL GAUGE NETWORK**	**STREAMS INSIDE OF LANL GAUGE NETWORK**
Ephemeral	Upland, soil, and soil-associated resources assumed to be present outside of the summer monsoon season. Within the monsoon season, the potential for sediment and sediment-associated resources is assumed.	Upland, soil, and soil-associated resources assumed to be present outside of summer monsoon season, unless riparian surveys indicate presence of riparian habitat; in which case sediment and sediment-associated resources assumed to also be present.
Intermittent	Intermittent streams within the LANL boundary have an average of 33% of days of flow throughout the year. Most of this flow occurs in the spring snowmelt and summer monsoon seasons (March through September). In areas where only stream class is known, assume sediment and sediment-associated resources present 33% of the time and soil and soil-associated resources present 67% of the time.	Stream segments inside LANL with data on flow frequency assumed to have soil and soil-associated resources or sediment and sediment-associated resources present in proportion to flow frequency. Portions of intermittent streams with surveyed riparian habitats in riparian surveys assumed to have sediment and sediment-associated resources present year-round.
Perennial	Sediment and sediment associated resources assumed to be present.	Sediment and sediment-associated resources assumed to be present.

5.2.2 SPECIES OF PARTICULAR INTEREST TO THE NRDA

Despite the numerous environmental monitoring and field survey programs at LANL, some gaps in the understanding of LANL habitats and associated species remain. For purposes of the NRDA, however, available information is sufficient.

Exhibit 5-2 presents species that may be considered in greater detail in subsequent steps in the NRDA process. It is based on surveys and studies conducted on the Pajarito Plateau (presented in Section 3.3) and suggestions by the LANL Trustees, and focuses on species that are common in the area, have been studied extensively, or may be important for cultural or conservation purposes. However, Exhibit 5-2 is not intended to be a definitive list of all the species that may be present within LANL and the surrounding areas or that may have been injured by releases of hazardous substances from LANL operations. Songbird species included in Exhibit 5-2 vary by canyon and land cover type. Additionally, as mentioned in Section 3.3.1, songbird community composition has shifted between 2010 and 2018 as a likely response to climatic change (LA-UR-19-23767). Nonetheless, the songbirds included in Exhibit 5-2 may be targeted for evaluation in the NRDA and additional species may be added as information becomes available.

EXHIBIT 5-2. SPECIES OF PARTICULAR INTEREST TO THE LANL NRDA

BIOLOGICAL RESOURCE	SPECIES
Birds	Western bluebird, ash-throated flycatcher, **hawk**, **wild turkey**, **roadrunners**, **grouse**, **quail**, **the Mexican spotted owl**, **robin**, spotted towhee, broad-tailed hummingbird, lesser goldfinch, Wilson's warbler, and ruby-crowned kinglet.
Aquatic Vertebrates	Fish: Rio Grande cutthroat trout, Rio Grande sucker, Rio Grande chub, brook trout, and rainbow trout. Amphibians: spadefoot toad, green toad, red-spotted toad, woodhouse toad, canyon treefrog, leopard frog, the **Jemez Mountains Salamander** and juvenile tiger salamander.
Mammals	Large mammals: mule deer, Jemez Mountains elk, and coyote. Small mammals: spotted bat, Occult little brown bat, **goat peak pika** and deer mouse.
Benthic Macroinvertebrates	Ephemeral-intermittent streams (when seasonally flowing): benthic worms (*Naididae*) and biting midge fly larvae (*Dasyhelea*). Perennial streams: riffle beetles (*Optioservus*) and round worms (*Nematoda*). Other: **Mayfly** and **caddisfly**.
Vegetation	Upland: one-seed juniper, piñon juniper, ponderosa pine, and Douglas fir. Riparian: narrowleaf cottonwood, sedges, willows, ponderosa pine, box elders, chokecherry shrubs, and cheatgrass.

Species in **bold** were added based on LANL Trustee suggestions.

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APPENDIX A | SUMMARY OF SURFACE WATER FLOW DATA FROM THE LANL STREAM GAUGE NETWORK

Exhibit A-1 summarizes the calculated flow parameters (calculations described in detail in Section 3.2.1) for all stream gauges in the LANL gauge network. For each gauge, its associated canyon is identified. Those gauges that have “N/A” in the Mean Daily Discharge and Max Daily Discharge columns have no pre-2012 data. Exhibit A-2 illustrates the locations of the tabulated stream gauges. Exhibit A-3 compares the NHD stream classification within LANL to the IEc-derived stream classifications.

EXHIBIT A-1. SUMMARY OF CALCULATED PARAMETERS FOR ALL GAUGES IN LANL STREAM GAUGE NETWORK

Gauge ID	Canyon	Years of Full Data	Mean Annual Flow Frequency (%)	Mean Flow Frequency (%) - Oct-Feb	Mean Flow Frequency (%) - March-June	Mean Flow Frequency (%) - July-Sept	Years of Full Data (Pre-2012)	Mean Daily Discharge (cfs)	Max Daily Discharge (cfs)
E025	Los Alamos	9	44%	23%	66%	47%	9	0.2945	4.1444
E026	Los Alamos	12	36%	20%	51%	38%	9	0.3644	5.8789
E026.85	Los Alamos	3	38%	16%	77%	24%	3	0.4089	4.6333
E030	Los Alamos	19	20%	7%	33%	23%	16	0.2458	3.8181
E038	Los Alamos	11	23%	14%	20%	41%	8	0.1341	7.8375
E039	Los Alamos	7	30%	18%	42%	34%	7	0.1154	5.3714
E039.1	Los Alamos	4	46%	49%	54%	59%	1	0.0639	7.2300
E040	Los Alamos	13	12%	9%	10%	17%	11	0.0430	3.7500
E042	Los Alamos	15	14%	3%	25%	15%	15	0.2025	6.6660
E042.1	Los Alamos	3	8%	5%	5%	17%	0	N/A	N/A
E050	Los Alamos	8	13%	4%	24%	17%	8	0.2005	5.8088
E050.1	Los Alamos	5	8%	9%	4%	23%	1	0.1002	8.7000
E055	Los Alamos	11	30%	21%	34%	42%	6	0.2227	16.6367
E055.5	Los Alamos	10	12%	9%	16%	28%	7	0.0328	3.5700
E056	Los Alamos	8	31%	20%	25%	52%	5	0.0498	7.5600
E059	Pueblo	1	0%	0%	0%	1%	0	N/A	N/A
E059.5	Pueblo	2	88%	97%	73%	79%	0	N/A	N/A
E059.8	Pueblo	2	63%	90%	37%	20%	0	N/A	N/A
E060	Pueblo	14	88%	93%	87%	79%	14	0.7909	15.5243
E060.1	Pueblo	3	6%	5%	1%	11%	0	N/A	N/A
E089	Guaje	3	3%	2%	3%	7%	3	0.0629	13.7667

Gauge ID	Canyon	Years of Full Data	Mean Annual Flow Frequency (%)	Mean Flow Frequency (%) - Oct-Feb	Mean Flow Frequency (%) - March-June	Mean Flow Frequency (%) - July-Sept	Years of Full Data (Pre-2012)	Mean Daily Discharge (cfs)	Max Daily Discharge (cfs)
E090	Guaje	2	3%	0%	2%	8%	2	0.0377	9.4500
E099	Guaje	0	N/A	1%	4%	51%	0	N/A	N/A
E109.9	Guaje	1	47%	64%	69%	43%	0	N/A	N/A
E121	Sandia	8	100%	100%	98%	100%	6	0.5943	2.4000
E121.9	Sandia	4	8%	2%	7%	19%	4	0.0017	0.0800
E122	Sandia	6	96%	94%	99%	99%	3	0.0678	1.1167
E122.2	Sandia	3	5%	2%	5%	11%	3	0.0021	0.2133
E122.3	Sandia	3	2%	1%	1%	4%	3	0.0003	0.0433
E122.35	Sandia	3	2%	1%	1%	6%	3	0.0003	0.0233
E122.5	Sandia	4	10%	5%	6%	24%	4	0.0046	0.2000
E123	Sandia	10	100%	100%	100%	100%	8	0.6206	5.0125
E123.4	Sandia	3	8%	2%	4%	22%	3	0.0038	0.1967
E124	Sandia	0	N/A	N/A	2%	N/A	0	N/A	N/A
E125	Sandia	18	0%	0%	0%	1%	16	0.0025	0.8319
E196	Mortandad	3	5%	4%	4%	7%	3	0.0016	0.1633
E200	Mortandad	13	57%	51%	57%	67%	13	0.0507	3.1677
E200.5	Mortandad	3	4%	1%	3%	10%	3	0.0018	0.1333
E201	Mortandad	5	4%	14%	0%	5%	3	0.0043	1.1333
E201.1	Ten-Site	3	8%	3%	8%	16%	3	0.0027	0.2033
E201.3	Ten-Site	3	7%	3%	6%	14%	3	0.0022	0.1400
E201.5	Ten-Site	9	2%	3%	0%	2%	6	0.0076	2.2650
E202	Mortandad	12	1%	0%	0%	2%	12	0.0025	0.7392
E203	Mortandad	12	0%	0%	0%	0%	12	0.0024	0.8667
E204	Mortandad	19	0%	0%	0%	1%	16	0.0000	0.0000
E218	Canada del Buey	8	10%	2%	14%	19%	8	0.0141	1.7675
E220	Canada del Buey	3	3%	2%	3%	4%	3	0.0003	0.0267
E223	Canada del Buey	3	1%	1%	0%	2%	3	0.0001	0.0133
E225	Canada del Buey	14	0%	0%	0%	0%	14	0.0001	0.0479
E227	Canada del Buey	3	0%	1%	0%	1%	3	0.0001	0.0133
E229.3	Canada del Buey	0	N/A	N/A	3%	22%	0	N/A	N/A
E230	Canada del Buey	14	2%	1%	1%	6%	14	0.0089	1.5871
E240	Pajarito	13	25%	8%	28%	35%	12	0.0695	2.3125
E241	Pajarito	8	72%	80%	76%	65%	8	0.0582	9.8825
E242	Pajarito	9	97%	94%	99%	100%	9	0.2492	4.2378

Gauge ID	Canyon	Years of Full Data	Mean Annual Flow Frequency (%)	Mean Flow Frequency (%) - Oct-Feb	Mean Flow Frequency (%) - March-June	Mean Flow Frequency (%) - July-Sept	Years of Full Data (Pre-2012)	Mean Daily Discharge (cfs)	Max Daily Discharge (cfs)
E242.5	Pajarito	8	85%	92%	78%	84%	8	0.0386	0.5375
E243	Pajarito	6	52%	30%	62%	53%	6	0.2647	6.4317
E243.5	Pajarito	4	11%	5%	9%	25%	4	0.0066	0.3300
E244	Pajarito	4	34%	28%	40%	48%	4	0.1197	18.2700
E245	Pajarito	14	22%	12%	36%	21%	14	0.1860	8.8700
E245.5	Pajarito	5	24%	21%	24%	8%	5	0.2434	7.6880
E246	Three-Mile	9	13%	8%	24%	3%	8	0.0212	1.9888
E247	Pajarito	3	0%	1%	0%	1%	3	0.0001	0.0233
E248	Pajarito	3	1%	1%	0%	4%	3	0.0014	0.2800
E248.5	Pajarito	3	1%	2%	1%	2%	3	0.0007	0.0967
E249	Pajarito	3	0%	0%	0%	1%	3	0.0001	0.0167
E249.5	Pajarito	5	8%	7%	5%	15%	5	0.0038	0.2980
E250	Pajarito	15	13%	9%	17%	5%	14	0.0452	2.6507
E252	Water	13	81%	71%	78%	74%	13	0.0908	1.0854
E252.5	Water	1	68%	92%	94%	27%	1	0.0610	0.2000
E252.8	Water	6	2%	1%	1%	5%	6	0.0101	2.2783
E253	Canon de Valle	13	1%	0%	3%	1%	13	0.0141	0.6092
E256	Canon de Valle	6	66%	60%	81%	64%	6	0.0651	1.2600
E256.5	Canon de Valle	2	9%	3%	8%	22%	2	0.0019	0.0700
E257	Canon de Valle	3	6%	2%	13%	9%	3	0.0029	0.2167
E262	Canon de Valle	8	9%	4%	11%	13%	8	0.0132	1.1650
E262.4	Water	1	9%	3%	7%	28%	1	0.0022	0.0700
E262.5	Water	8	21%	19%	29%	13%	8	0.1348	4.7775
E263	Water	8	4%	1%	6%	6%	8	0.0594	7.5750
E264	Water	3	1%	0%	2%	1%	3	0.0001	0.0067
E265	Water	14	3%	1%	4%	5%	13	0.0340	3.9054
E267	Potrillo	14	1%	0%	0%	2%	13	0.0027	0.4577
E267.4	Potrillo	3	1%	0%	21%	6%	3	0.0001	0.0267
E274	Ancho	2	1%	1%	0%	1%	2	0.0019	0.6550
E275	Ancho	17	1%	0%	0%	4%	15	0.0138	3.7333
E338	Chaquehui	5	3%	6%	0%	3%	2	0.0000	0.0000
E340	Chaquehui	3	1%	0%	0%	3%	1	0.0000	0.0000
E350	Frijoles	9	100%	100%	100%	100%	9	1.1501	13.1778

EXHIBIT A-2. MAP OF TABULATED GAUGES IN LANL STREAM GAUGE NETWORK

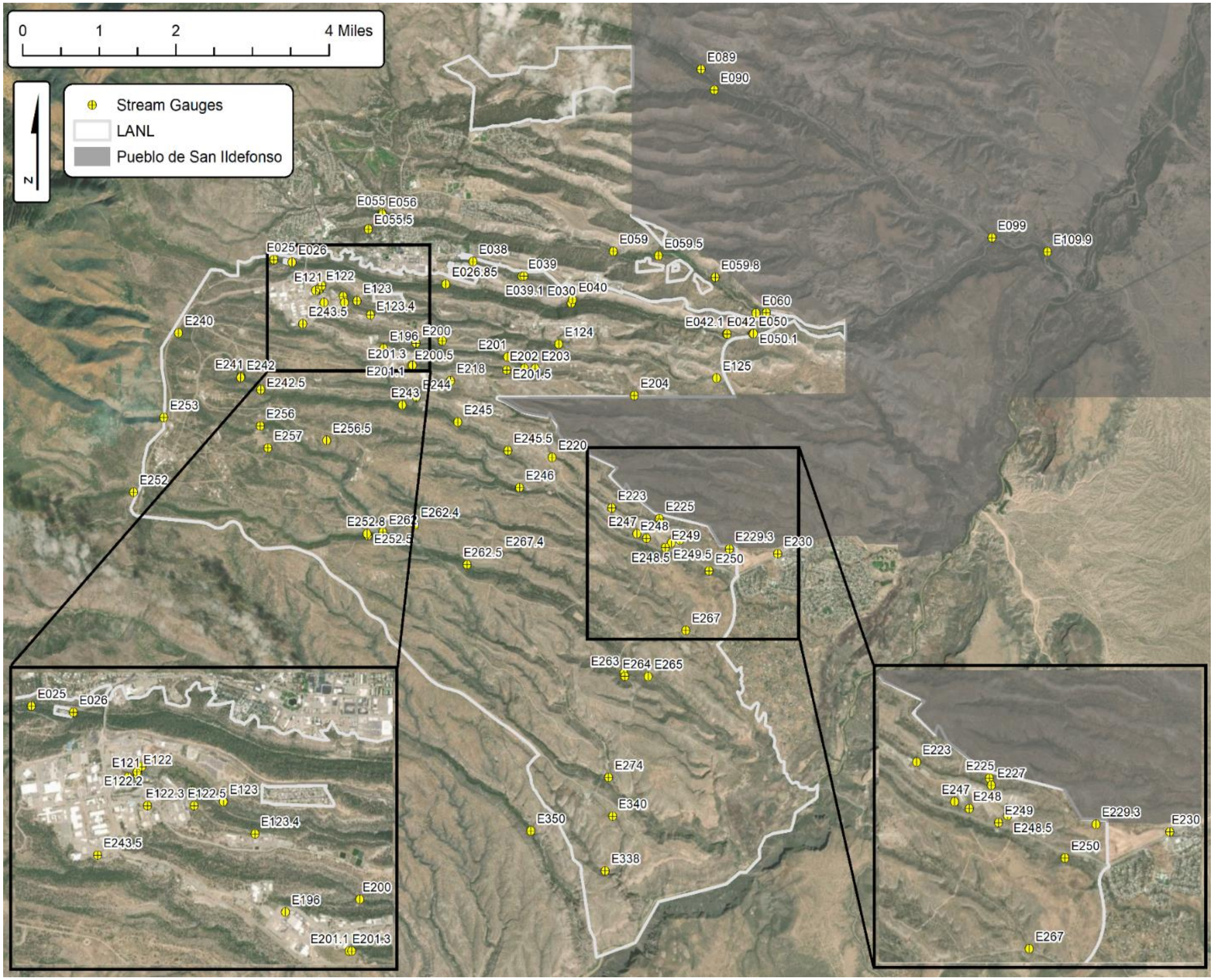
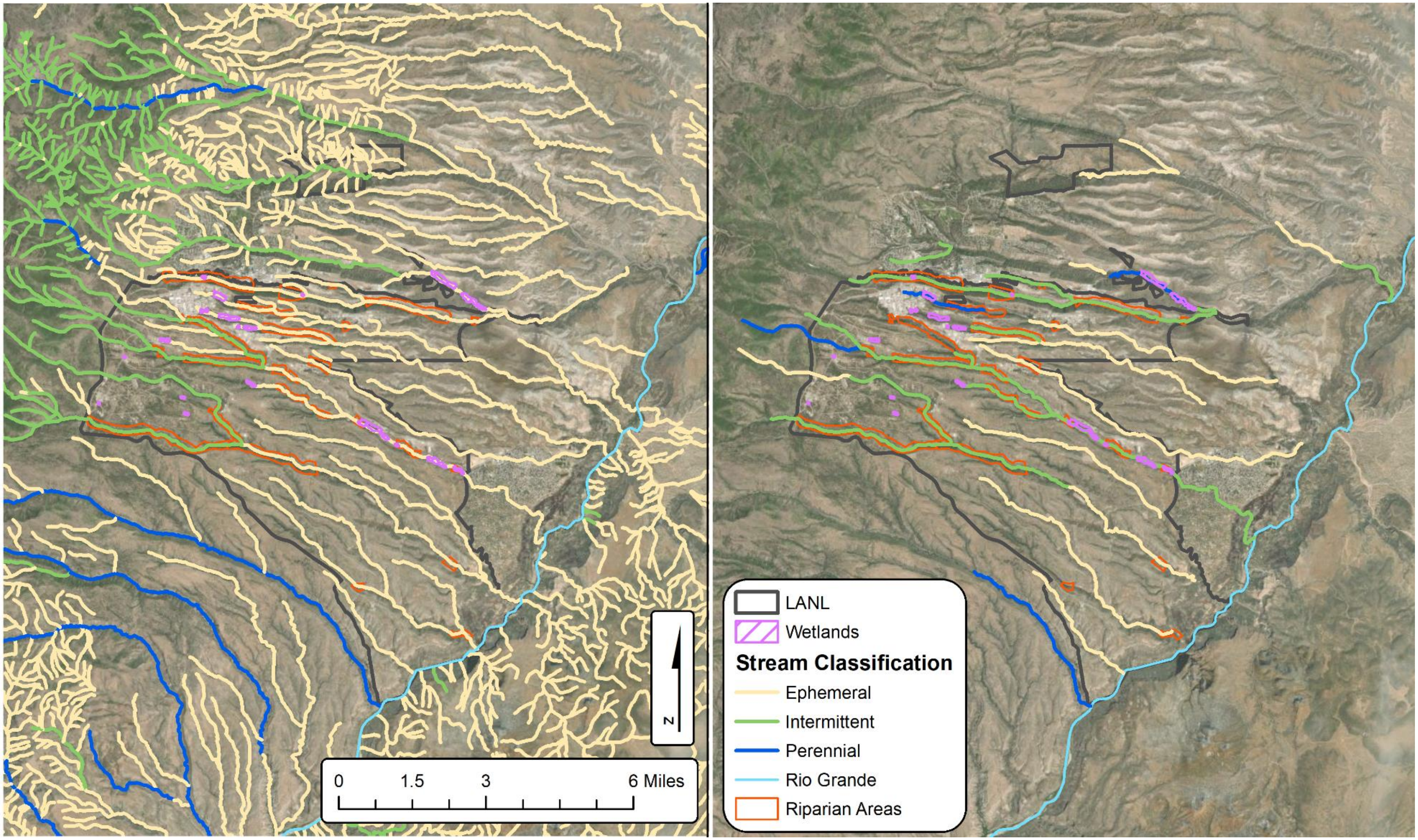


EXHIBIT A-3. COMPARISON OF NHD STREAM CLASSIFICATIONS (LEFT) AND IEc-DERIVED STREAM CLASSIFICATIONS (RIGHT)



APPENDIX B | CLIMATE ANALYSIS

Climate Context

The surface water flow data compiled from the LANL gauge network span from 1994 to 2017. Within a climatic context, this timeframe theoretically represents a snapshot of hydrologic conditions. However, Northern New Mexico has been experiencing higher temperatures and lower precipitation since the early 1990s and is currently experiencing drought conditions that are likely to persist into the future (LA-UR-17-21060, Dai et al. 2013, Cayan et al. 2010, IPCC 2021). Therefore, against this backdrop of a changing climate at the regional scale, as a preliminary step toward characterizing the flow regimes of LANL canyon streams, the extent to which climactic conditions are static or changing across the temporal scope are evaluated.

The spatial scope spans an elevation gradient from 6,200 feet near the edge of White Rock Canyon to 7,800 feet in elevation near the Jemez Mountains (LA-UR-17-21060). Canyon streams at the headwaters experience different precipitation and temperatures compared to canyon reaches near the confluence with the Rio Grande. Canyon stream flow is dominated by snow melt from the Jemez Mountains in the early spring (March and April) and monsoonal storms in the summer (July through September).

To identify climatic variations and trends within the observation window, annual climatic conditions are compared to a climate baseline.[25] The climatic baseline is represented by the climate normals for meteorological stations that span the elevation gradient. The World Meteorological Organization (WMO) defines the climate normal as the arithmetic mean of a climate element (e.g., temperature) over a 30-year period (WMO 1989). By convention, the current climate normals are based on the previous three decades (1980 to 2010); updated climate normals (1990 to 2020) will be available after 2020.

By comparing the annual data to climate normals, climatic anomalies are assessed. Anomalies are defined as a departure from a long-term average. When evaluating anomalies, it is important to focus on the magnitude of those anomalies instead of only exceedances or non-exceedances because the normals are presented as averages with no additional information on standard deviation. Therefore, this analysis highlights time periods that strongly deviate from the long-term average. Specifically, monthly precipitation and temperature anomalies are evaluated in the Pajarito Plateau between 1990 and 2020 based on data from the meteorological stations of White Rock (TA-54) at 6,500 feet in elevation and the Los Alamos station (TA-06) at 7,500 feet in elevation (LANL Weather Machine 2020a, 202b). These weather stations are selected because they are located among the LANL gauge network and because they are representative of the elevation gradient within the spatial scope.

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[25] This reference to baseline in the climatic context is used to mean the typical climatic conditions of the area. This is not to be confused with the NRDA use of the word baseline as *"the condition or conditions that would have existed at the assessment area had the discharge of oil or release of the hazardous substance under investigation not occurred"* (43 C.F.R. 11.14(e)).

Method for Determining Climate Anomalies

The current climate normals are calculated based on data from 1980 to 2010 from the Los Alamos and White Rock weather stations (LANL Weather Machine 2020a, 2020b) (Exhibit B-1). The normals are calculated as the mean monthly temperature in degrees Fahrenheit (^oF) and mean monthly precipitation in inches (in) over the record period. Los Alamos and White Rock station daily data from 1990 through June 2020 are presented as total daily precipitation (rain plus any snow-water equivalent). Therefore, calculations are determined from total monthly precipitation by summing daily precipitation values for each month. For temperature, daily values are available as mean maximum and mean minimum temperature. Therefore, the mean monthly temperature is calculated as the arithmetic mean of all maximum and minimum values.

Precipitation anomalies are determined by subtracting the calculated mean monthly precipitation from the precipitation normals. Similarly, temperature anomalies are calculated by subtracting the mean monthly temperature from the temperature normals.

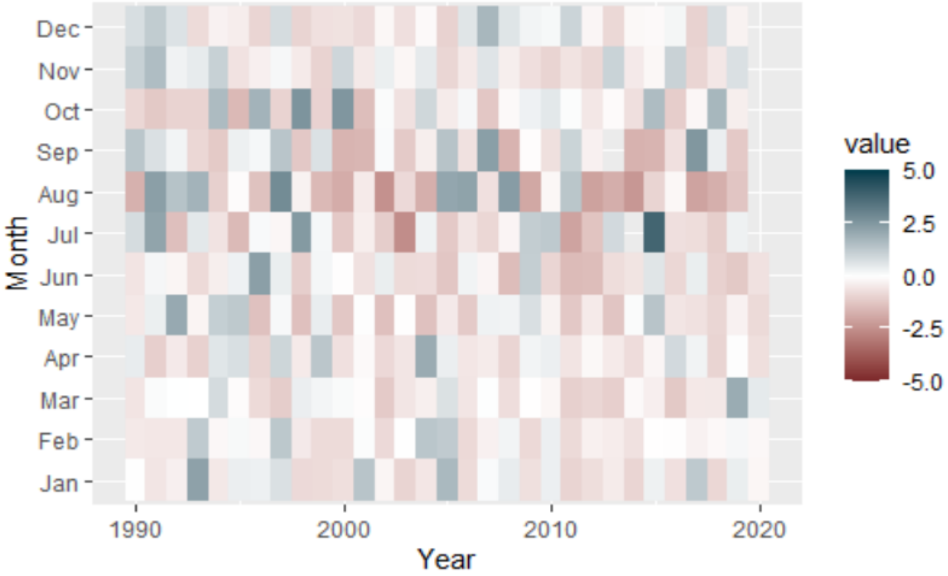
EXHIBIT B-1. 1980 TO 2010 CLIMATE NORMALS FOR LOS ALAMOS AND WHITE ROCK WEATHER STATIONS

MONTH	LOS ALAMOS TEMPERATURE NORMALS (°F)	LOS ALAMOS PRECIPITATION NORMALS (IN)	WHITE ROCK TEMPERATURE NORMALS (°F)	WHITE ROCK PRECIPITATION NORMALS (IN)
January	29.4	1.0	29.5	0.7
February	32.9	0.9	34.2	0.6
March	39.4	1.2	41.3	1.0
April	46.8	1.1	48.7	0.8
May	56	1.4	57.9	1.1
June	65.1	1.5	66.8	1.1
July	68.2	2.8	70.8	1.9
August	65.8	3.6	68.7	2.4
September	59.8	2.0	61.7	1.5
October	49.2	1.6	50.2	1.5
November	37.9	1.0	38.5	0.8
December	29.4	1.0	29.4	0.8
Annual	**48.3**	**19.0**	**49.8**	**14.2**

Los Alamos Meteorological Station (TA-06)

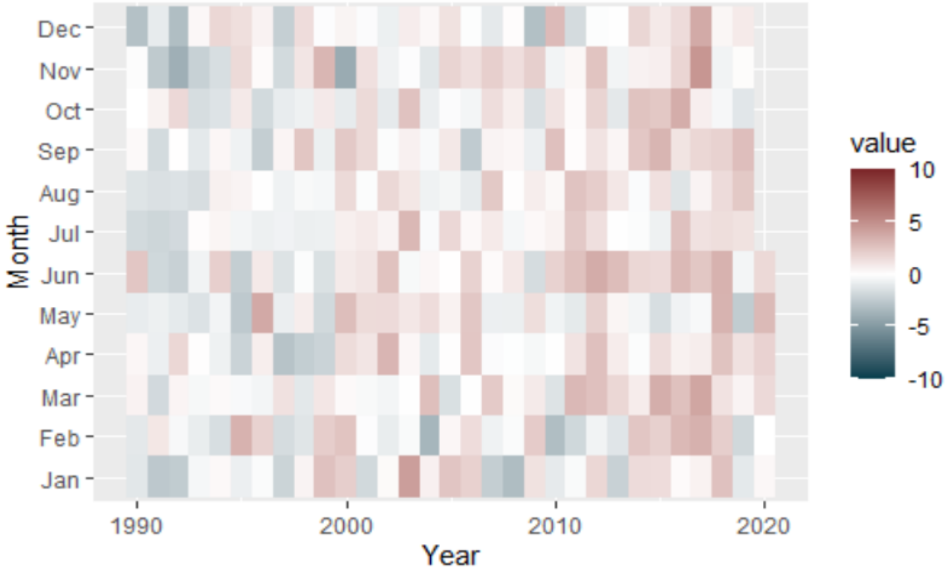
The Los Alamos meteorological station is situated at 7,500 feet in elevation and represents the upper elevation endmember of the climate sequence. Exhibit B-2 shows the results of the precipitation anomalies by month (y-axis) and year (x-axis). The magnitude of the anomalies (between +5 or -5 in from the normal) is represented by the intensity of the blue and red colors. The lighter the color of the square, the closer that month was to the climatic normal. The months of July, August, and September had the highest anomalies during the 30-year period. Starting in 2005, negative anomalies associated with drier conditions become more frequent during the year, particularly for the months of January through June.

EXHIBIT B-2. PRECIPITATION ANOMALIES (IN) BETWEEN 1990 AND 2020 FOR THE LOS ALAMOS WEATHER STATION



The temperature data for Los Alamos station do not show a seasonal pattern of significant anomalies (greater than 2.5 °F or less than -2.5 °F) during the summer months of July, August, and September (Exhibit B-3). Nonetheless, the inflection year when higher mean monthly temperature anomalies begin to dominate is approximately the year 2000. After the year 2000, positive anomalies that suggest warmer temperatures than normal are dominant with some of the largest positive deviations between 2010 and 2020.

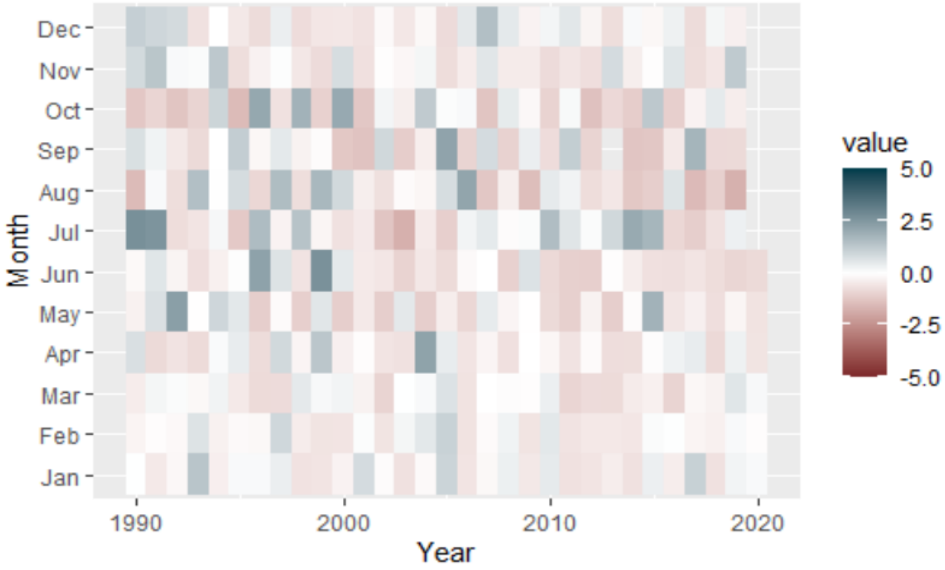
EXHIBIT B-3. TEMPERATURE ANOMALIES (°F) BETWEEN 1990 AND 2020 FOR LOS ALAMOS WEATHER STATION



White Rock Meteorological Station (TA-54)

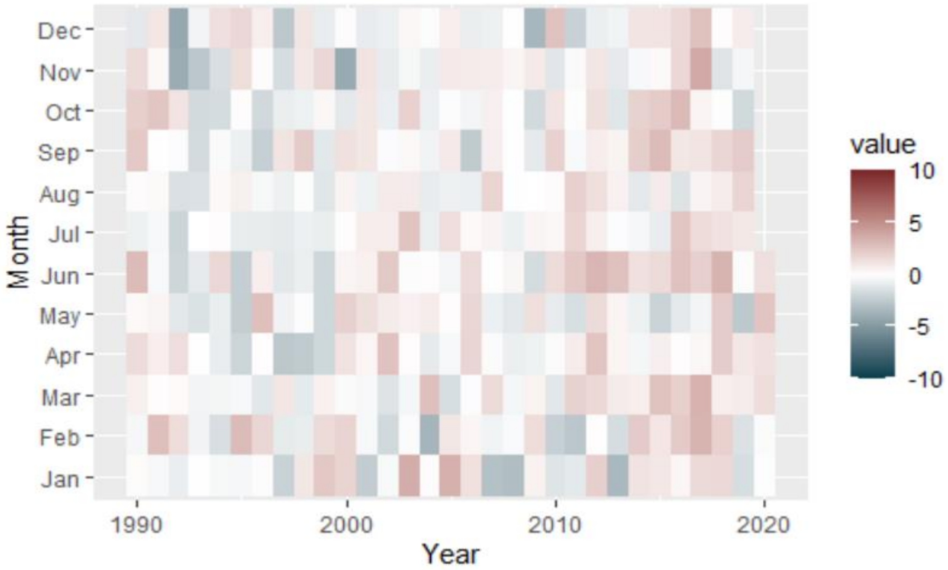
The White Rock meteorological station is situated at 6,500 feet in elevation and represents the lower elevation endmember of the climate sequence. Contrary to the observations at Los Alamos station, the months of July, August, and September do not show significant precipitation anomalies (Exhibit B-4). There are some positive anomalies particularly for the month of July. However, the magnitude and frequency are less than that observed in the Los Alamos weather station. Again, starting in the early 2000s (approximately in year 2006), a shift to more positive anomalies is observed, signaling a trend towards drier conditions.

EXHIBIT B-4. PRECIPITATION ANOMALIES (IN) BETWEEN 1990 AND 2020 FOR WHITE ROCK WEATHER STATION



At the White Rock weather station, the inflection year when positive temperature anomalies begin to dominate is in the year 2010 (Exhibit B-5). This is approximately ten years later than that observed at the Los Alamos weather station. Additionally, the magnitudes of the anomalies are less pronounced than those at the Los Alamos weather station, with positive anomalies closer to zero (lighter red color).

EXHIBIT B-5. TEMPERATURE ANOMALIES (°F) BETWEEN 1990 AND 2020 FOR WHITE ROCK WEATHER STATION



Implications of Climatic Trends for Stream Segment Classification

Based on the climate anomalies analysis, drier conditions and higher temperatures are becoming more common within the spatial scope. For the Los Alamos weather station, precipitation patterns are observed both seasonally and annually. First, the summer months of July, August, and September are characterized by anomalous precipitation conditions with respect to the climate normals. This is likely the result of brief monsoonal storm showers that result in deviations from the long-term precipitation normals. Precipitation anomalies in the Los Alamos weather station during the summer are bidirectional, meaning that there has been an even distribution of positive and negative anomalies. Nonetheless, the long-term trend of precipitation anomalies shows that negative anomalies (drier conditions) are becoming more common starting in the year 2000. At the White Rock weather station, which is at a lower elevation, the summer months do not appear to deviate from the climatic normals as observed in the higher elevation Los Alamos station. Additionally, a shift towards drier conditions is observed starting in the year 2010.

Surface water flow is influenced by climate and reflects precipitation patterns in the region. Besides inter-annual climatic variability, long-term climatic trends suggest that higher temperatures and drought in northern New Mexico will persist into the future because of climate change (Dai et al. 2013, Cayan et al. 2010, IPCC 2021). The compiled LANL stream gauge data span from 1995 through 2017. Therefore, the dataset contains surface flow observations before and after the early 2000s when climatic conditions enter a period of higher temperatures and less precipitation known as the 21st century drought (Cayan et al. 2010). The transition begins at the midpoint of the observation window of surface water flow, suggesting that some of the stream flow observations occurred during a transitional climatic state. However, not all gauges in the LANL gauge network have observations that span from 1990 through 2020. Considering these data limitations, all available data for each stream gauge are used to capture the flow variations at each location despite the influence of climatic variability. Thus, for the analysis on surface flow frequency (Section 3.2.1), all available flow data are combined to generate summary hydrologic parameters such as mean annual flow frequency.

APPENDIX B REFERENCES

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APPENDIX C | RIPARIAN HABITATS IN LOS ALAMOS NATIONAL LABORATORY CANYONS

Exhibit C-1 presents a summary of the compilation of riparian habitats information and associated plant species for canyons that intersect LANL. This summary relies primarily on LANL riparian inventories. LANL biologists inventoried riparian areas between 2007 and 2011 as part of the implementation of LANL's Biological Resources Management Plan (LA-UR-11-04768, LA-UR-12-20277).

EXHIBIT C-1. COMPILATION OF RIPARIAN HABITATS AND ASSOCIATED PLANT SPECIES FOR LANL CANYONS

CANYON	CANYON SEGMENT	HABITATS	PLANT COMMON NAMES
Sandia	Upper Sandia	SANDIA3 Site - Ponderosa Pine - Box Elder / Brome sp. Woodland	Overstory vegetation – boxelder, New Mexico locust, and ponderosa pine.
Sandia	Upper Sandia	SANDIA3 Site - Ponderosa Pine - Box Elder / Brome sp. Woodland	Understory vegetation – cheatgrass, Mexican dock, milkweed, James' galleta grass, mountain muhly, woods rose, Russian thistle, and wax current.
Pajarito	Bulldog Gulch	Mixed conifer / Gambel's Oak Woodland	Overstory vegetation - Douglass fir, Gambel's oak, chokecherry, and quaking aspen.
Pajarito	Bulldog Gulch	Mixed conifer / Gambel's Oak Woodland	Understory vegetation - Mountain muhly, chokecherry, Colorado barberry, brome grass, and wax current.
Pajarito	Upper Pajarito	Site 1: Mixed conifer – Water Birch / Mixed Grasses Forest	Overstory vegetation - water birch, Douglass fir, White fir, and Gambel's oak.
Pajarito	Upper Pajarito	Site 1: Mixed conifer – Water Birch / Mixed Grasses Forest	Understory vegetation - smooth brome, horsetail, redtop, Colorado barberry, fivepetal cliffbush, and boxelder.
Pajarito	Upper Pajarito	Site 2: Narrowleaf Cottonwood / Red Raspberry – New Mexico Locust Forest	Overstory vegetation - narrowleaf cottonwood.
Pajarito	Upper Pajarito	Site 2: Narrowleaf Cottonwood / Red Raspberry – New Mexico Locust Forest	Understory vegetation - smooth brome, red raspberry, New Mexico locust, cutleaf coneflower, Poa, horsetail, ferns, mountain nettle, fivepetal cliffbush, wax current, and muttongrass.
Pajarito	Upper Pajarito	Site 3 and 4: Mixed Conifer / Gambel's Oak Woodland	Overstory vegetation – Gambel's oak, Douglas fir, white fir, and chokecherry.
Pajarito	Upper Pajarito	Site 3 and 4: Mixed Conifer / Gambel's Oak Woodland	Understory vegetation – smooth brome, chokecherry, mountain muhly, rock clematis, brackenfern, Virginia creeper, pale thistle, New Mexico locust, fivepetal cliffbush, water birch, Colorado barberry, poa, brome grass, wax current, woodland strawberry, Gambel's oak, and woods rose.
Pajarito	Mid Pajarito	Site FRS to 18: Coyote Willow / Mixed Grasses Woodland	Overstory vegetation - narrowleaf willow, narrowleaf cottonwood, and box elder

CANYON	CANYON SEGMENT	HABITATS	PLANT COMMON NAMES
Pajarito	Mid Pajarito	Site FRS to 18: Coyote Willow / Mixed Grasses Woodland	Understory vegetation – redtop, cheatgrass, New Mexico locuts, slender wheatgrass, tall tumblemustard, prairie sagewort, McDougal verbena, Fendler's meadow-rue, woods rose, and James' beardtongue.
Pajarito	Mid Pajarito	Site FRS to 18b: Narrowleaf Cottonwood - Box Elder / Brome sp. Woodland	Overstory vegetation - narrowleaf cottonwood, and box elder.
Pajarito	Mid Pajarito	Site FRS to 18b: Narrowleaf Cottonwood - Box Elder / Brome sp. Woodland	Understory vegetation – cheatgrass, redtop, tufted evening primrose, tall tumblemustard, James' beardtongue, Fendler's meadow-rue, forbs, rock clematis, tarragon, and woods rose.
Pajarito	Lower Pajarito	Coyote Willow / Sedge sp. Shrubland	Overstory vegetation – none
Pajarito	Lower Pajarito	Coyote Willow / Sedge sp. Shrubland	Understory vegetation – narrowleaf willow, tarragon, sedge, grass, rush, forbs, cheatgrass, poa, common mullein, lambsquarters, alfalfa, basin big sagebrush, wheatgrass, skunkbush sumac, and New Mexico olive.
Pajarito	Lower Pajarito	Site 3: Sedge sp. Wooded Herbaceous Vegetation	Overstory vegetation - narrowleaf cottonwood.
Pajarito	Lower Pajarito	Site 3: Sedge sp. Wooded Herbaceous Vegetation	Understory - sedge, woods rose, little bluestem, Poa, squirreltail, narrowleaf cottonwood, grasses, forbs, cheatgrass, tarragon, and narrowleaf willow.
Pajarito	Lower Pajarito	Site 4: Narrowleaf Cottonwood / Redtop – Mixed Grasses Woodland	Overstory vegetation – narrowleaf cottonwood, and Russian olive.
Pajarito	Lower Pajarito	Site 4: Narrowleaf Cottonwood / Redtop – Mixed Grasses Woodland	Understory vegetation – redtop, poa, little bluestem, squirreltail, alfalfa, rush, sedge, brome grass, forbs, grasses, and witchgrass.
Mortandad	Cañada del Buey	Site 1: Riparian - Mixed conifer / Box Elder - Chokecherry Forest	Overstory - Douglas fir, box elder, and Ponderosa pine.
Mortandad	Cañada del Buey	Site 1: Riparian - Mixed conifer / Box Elder - Chokecherry Forest	Understory - cheatgrass, chokecherry, woods rose, common mullein, mountain muhly and Colorado barberry, and rock clematis.
Mortandad	Cañada del Buey	Site 2: Mixed conifer / Gambel's Oak Forest	Overstory vegetation – Gambel's oak, ponderosa pine, Douglas fir, and chokecherry.

CANYON	CANYON SEGMENT	HABITATS	PLANT COMMON NAMES
Mortandad	Cañada del Buey	Site 2: Mixed conifer / Gambel's Oak Forest	Understory vegetation – chokecherry, Colorado barberry, muttongrass, cheatgrass, common mullein, and mountain muhly.
Ancho	Lower Ancho	Site 1: Ponderosa Pine – Box Elder / New Mexico Olive – New Mexico Locust Forest	Overstory vegetation – boxelder and ponderosa pine.
Ancho	Lower Ancho	Site 1: Ponderosa Pine – Box Elder / New Mexico Olive – New Mexico Locust Forest	Understory vegetation - mountain muhly, New Mexico Locust, New Mexico olive, brome grass, boxelder, and Mexican dock.
Ancho	Ancho - Rio Grande	Valley Cottonwood - Box Elder / Coyote Willow Forest	Overstory vegetation - valley cottonwood, box elder, and Oneseed juniper.
Ancho	Ancho - Rio Grande	Valley Cottonwood - Box Elder / Coyote Willow Forest	Understory vegetation - narrowleaf willow, basin big sagebrush, boxelder, brome grass, and mountain muhly.
Water	Lower Water	Chokecherry – New Mexico Olive Wooded Shrubland	Overstory vegetation - box elder and Oneseed Juniper.
Water	Lower Water	Chokecherry – New Mexico Olive Wooded Shrubland	Understory vegetation – chokecherry, New Mexico olive, mountain muhly and squirreltail.
DP	Middle DP Canyon	Coyote Willow / Mixed Grasses Woodland	Overstory vegetation – narrowleaf willow, Oneseed juniper, and Gambel's oak.
DP	Middle DP Canyon	Coyote Willow / Mixed Grasses Woodland	Understory vegetation – narrowleaf willow, trailing fleabane, locoweed, grasses, mountain muhly, Rydberg's penstemon, and Mexican dock.
Two-Mile	Upper Two-Mile	Site 1: Mixed conifer / Gambel's Oak Forest	Overstory vegetation – flexible pine, Douglas fir, Gambel's oak, white fir, and chokecherry.
			Understory vegetation – chokecherry, muttongrass, fivepetal cliffbush, Colorado barberry, Northern bedstraw, and gooseberry.
Two-Mile	Upper Two-Mile	Site 2: Mixed Conifer / Gambel's Oak Woodland	Overstory vegetation – Douglas fir and Gambel's oak.

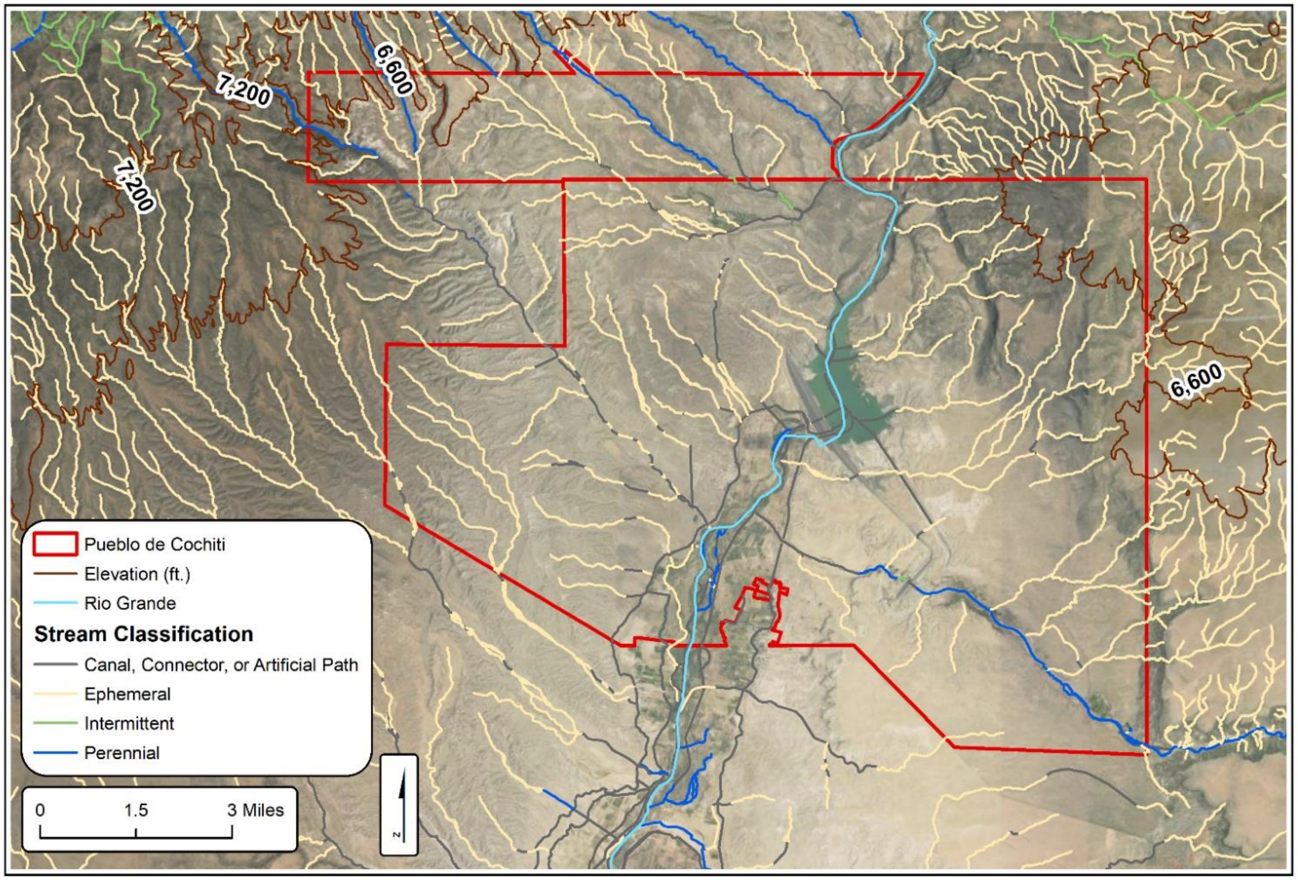
CANYON	CANYON SEGMENT	HABITATS	PLANT COMMON NAMES
			Understory vegetation – chokecherry, brome grass, muttongrass, fivepetal cliffbush, Colorado barberry, Northern bedstraw, thistle, and Gambel's oak.
Two-Mile	Upper Two-Mile	Site 2 Side-West: Mixed conifer / Box Elder - Chokecherry Forest	Overstory vegetation – Douglas fir, Rocky mountain maple, white fir, and Gambel's oak.
			Understory vegetation - red raspberry, mountain muhly, chokecherry, boxelder, Northern bedstraw, quaking aspen, fivepetal cliffbush, rock clematis, and redtop.
Two-Mile	Middle Two-Mile	Site 3: Mixed Conifer / Gambel's Oak Woodland	Overstory vegetation – ponderosa pine, flexible pine, and Douglas fir.
			Understory vegetation – wheatgrass, narrowleaf willow, Gambel's oak, mountain muhly, poison ivy, woods rose, and New Mexico locust.
Two-Mile	Middle Two-Mile	Site 4-P1: Mixed conifer / Gambel's Oak Forest	Overstory vegetation – Douglas fir, Gambel's oak, boxelder, white fir, and narrowleaf willow.
			Understory vegetation – mountain muhly, wheatgrass, chokecherry, narrowleaf willow, Gambel's oak, Northern bedstraw, Rocky mountain maple, poison ivy, red raspberry, woods rose, fivepetal cliffbush, rock clematis, and Colorado barberry.
Two-Mile	Lower Two-Mile	Site 4-P2: Box Elder Forest	Overstory vegetation – boxelder, white fir, and Douglas fir.
			Understory vegetation – ferns, red raspberry, Gambel's oak, common mullein, mountain muhly, and Northern bedstraw.

APPENDIX D | DETAILED LANDCOVER AND SURFACE WATER CONDITIONS ON TRUSTEE LANDS OUTSIDE OF LANL BOUNDARY

This appendix provides a summary of the stream classification from the NHD as it applies to Trustee lands. A map for each area considered is provided, highlighting the streams in the area; each stream's classification as ephemeral, intermittent, or perennial; and the associated elevation zones. In addition, maps of the ERU and NLCD designations are presented for selected Trustee lands.

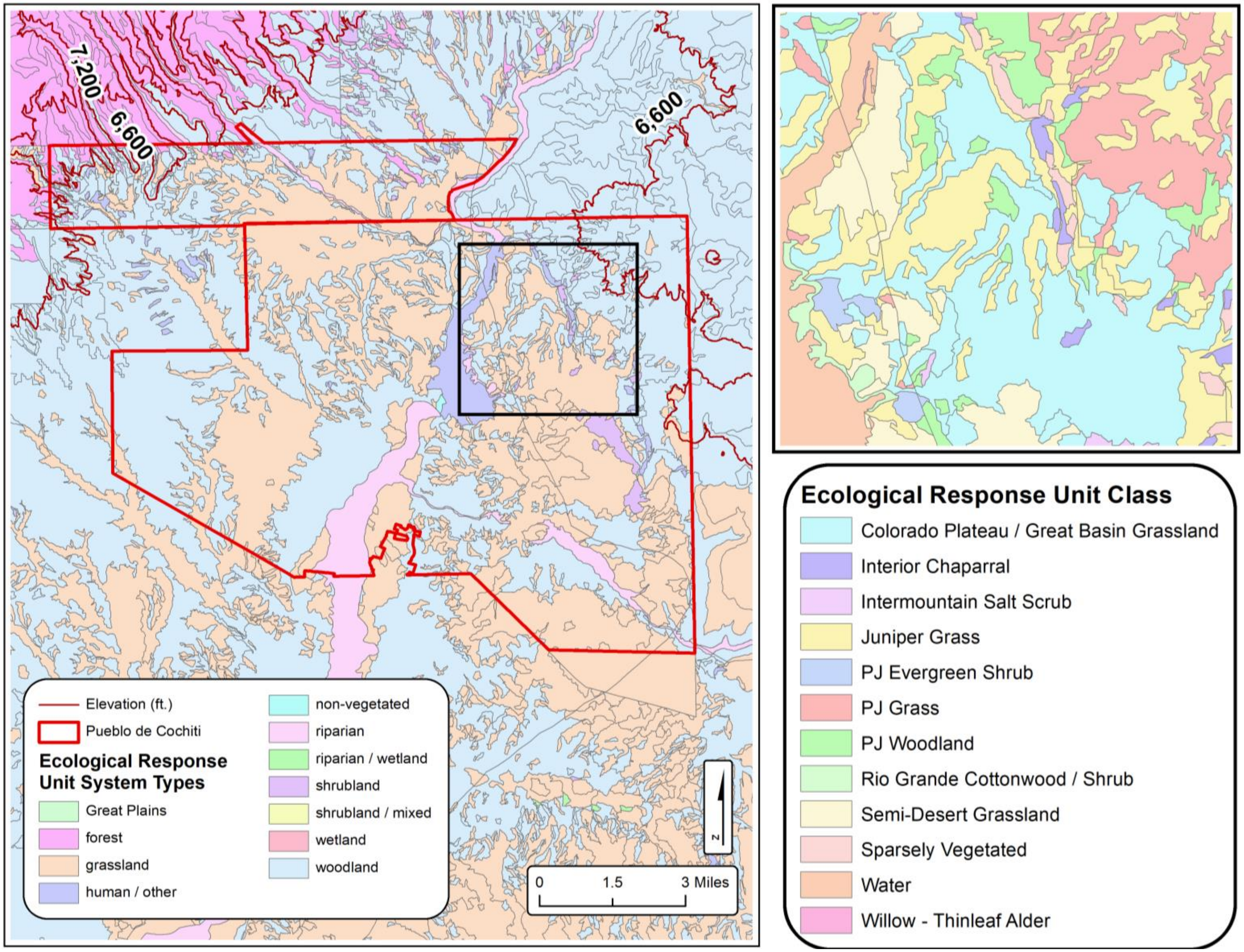
Pueblo de Cochiti

EXHIBIT D-1. STREAM AND ELEVATION ZONES IN PUEBLO DE COCHITI



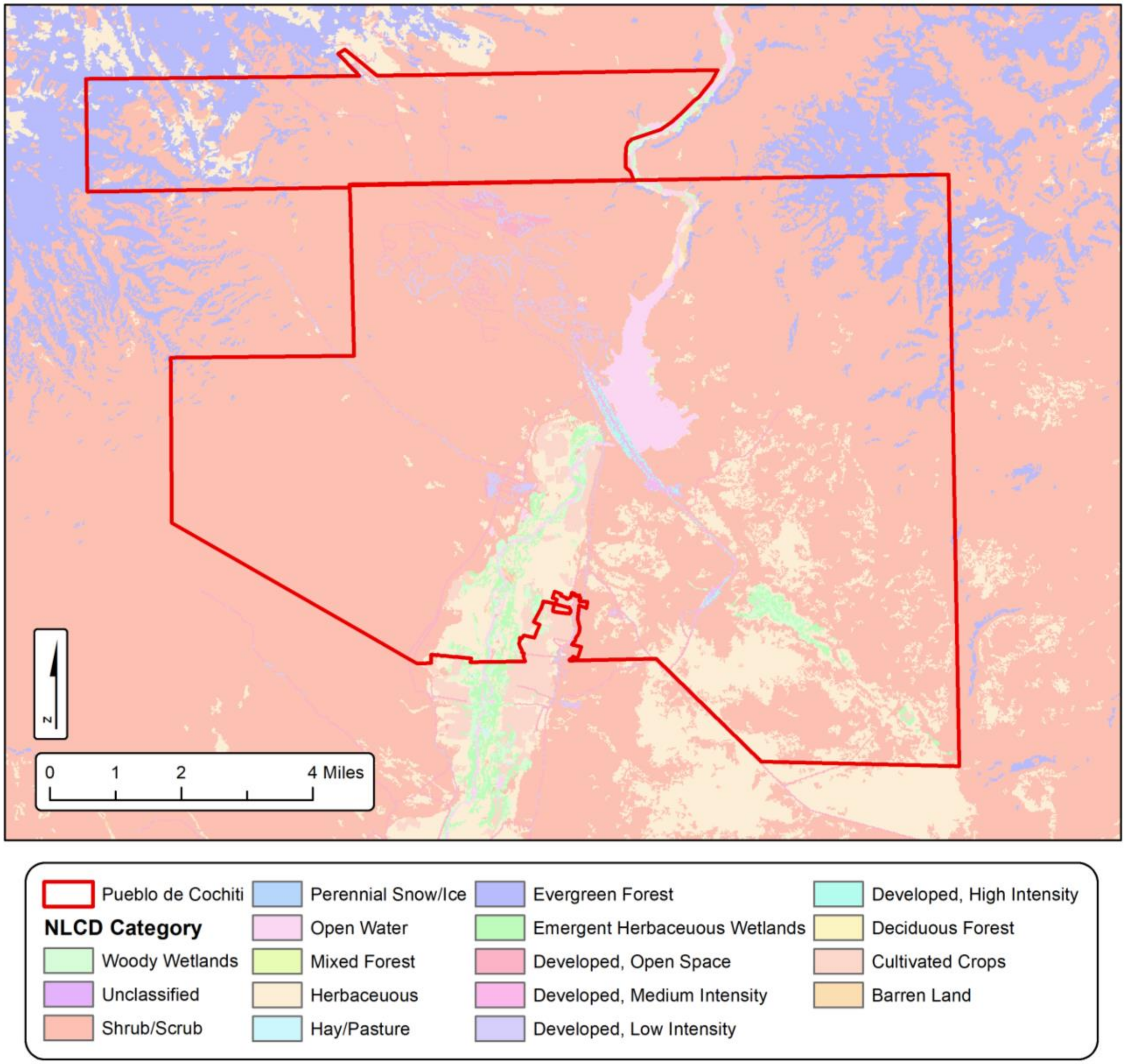
As is shown in Exhibit D-1, on Pueblo de Cochiti land, there are many ephemeral streams, and the perennial streams of the Rio Grande and the Santa Fe River, as well as several perennial streams in the north section of the Pueblo. The map also defines the elevations throughout the Pueblo, which shows that the majority of the Pueblo lands are below 6,600 feet, with a small portion between 6,600 and 7,200 feet. These elevation zones may be used to develop associations between elevation and vegetative communities to determine the habitat types and species likely present across the assessment where site-specific survey data are not available.

EXHIBIT D-2. ERU SYSTEM TYPE AND CLASS IN PUEBLO DE COCHITI



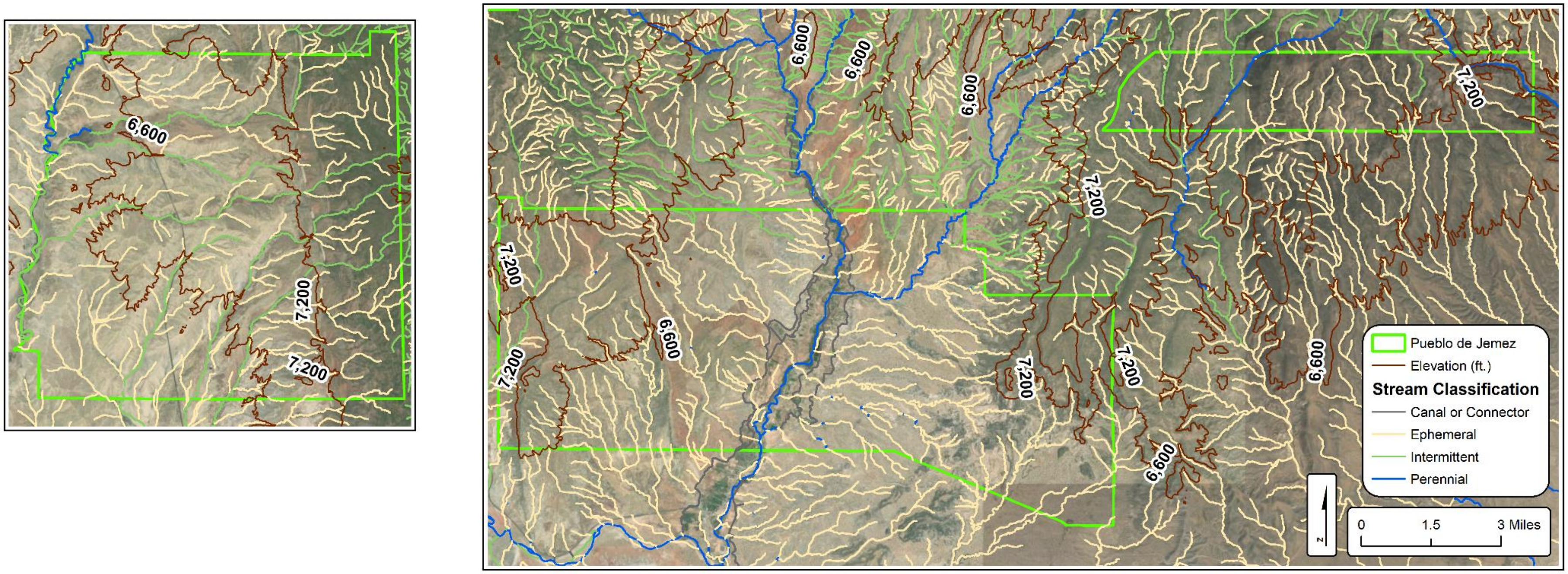
Note: Inset chosen as an example to display difference between the ERU System Type and Class.

EXHIBIT D-3. NLCD HABITAT DESIGNATIONS IN PUEBLO DE COCHITI



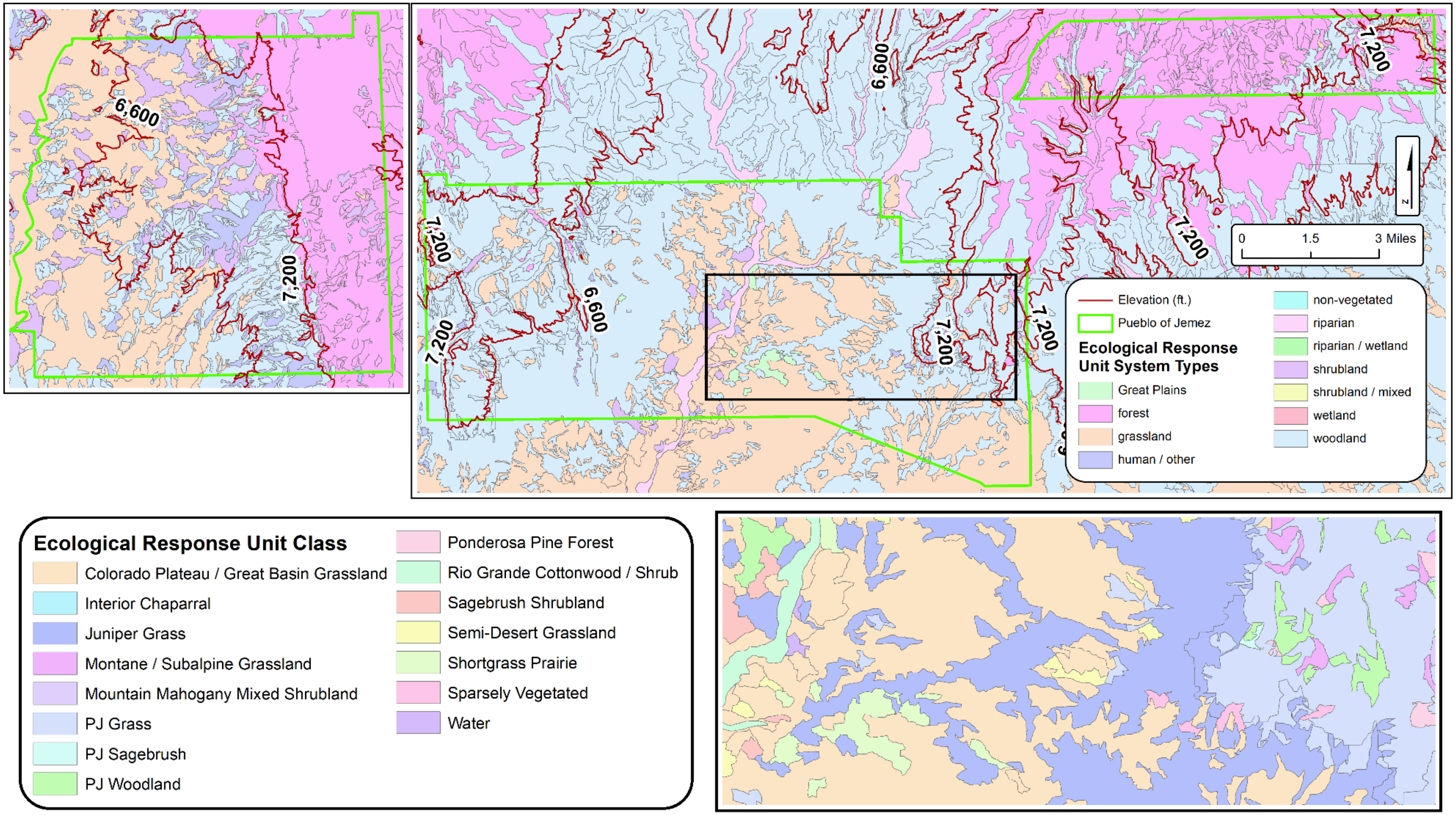
Pueblo of Jemez

EXHIBIT D-4. STREAM AND ELEVATION ZONES IN PUEBLO DE JEMEZ



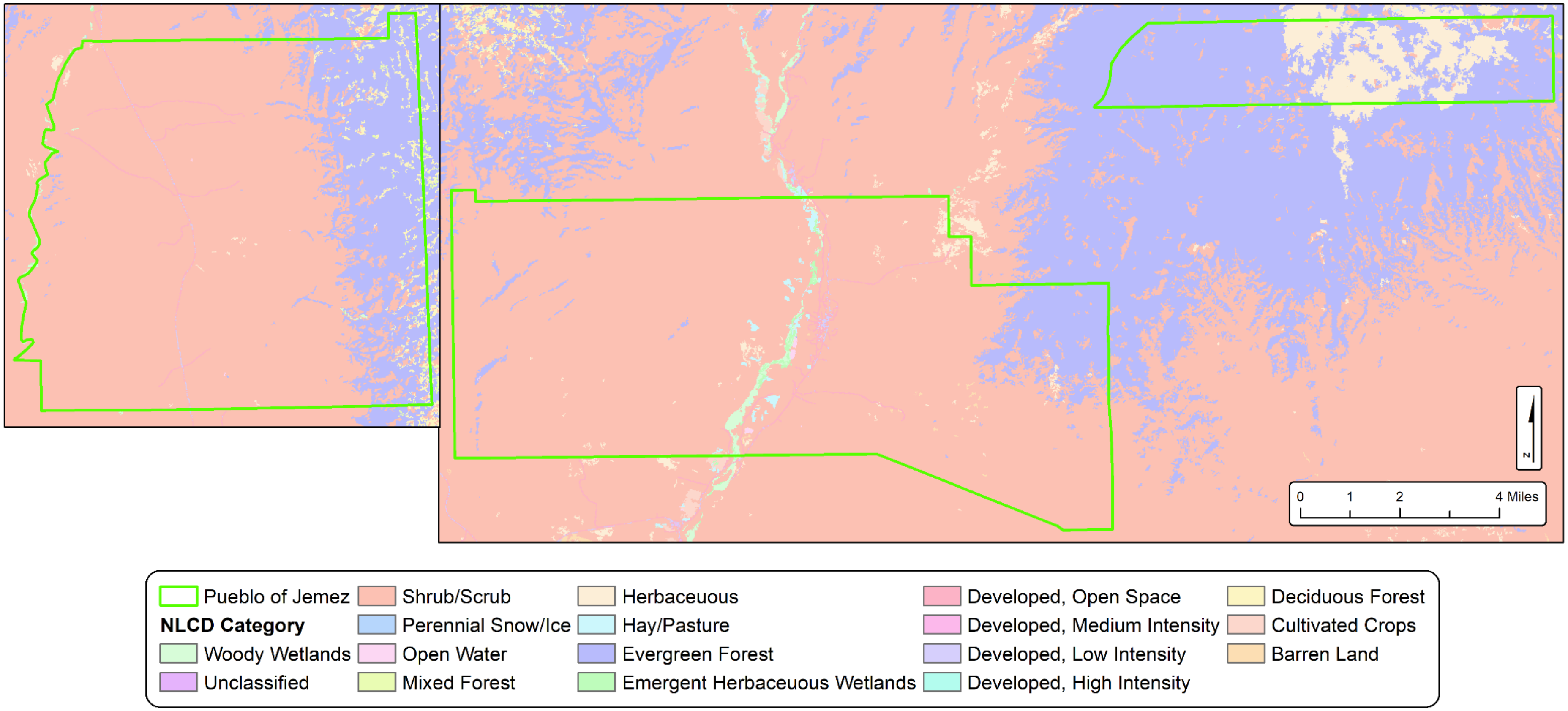
As is shown in Exhibit D-4, Pueblo de Jemez land contains many different types of streams and rivers across several elevation zones. The perennial streams on the Pueblo are the Jemez River and Vallecito Creek in the central area of the Pueblo, and two smaller perennial streams in the northeastern area of the Pueblo. The central area of the Pueblo is largely below 6,600 feet in elevation, while the northeastern and northwestern areas of the Pueblos are largely above 6,600 feet and sometimes above 7,200 feet. These elevation zones may be used to develop associations between elevation and vegetative communities to determine the habitat types and species likely present across the assessment where site-specific survey data are not available.

EXHIBIT D-5. ERU SYSTEM TYPE AND CLASS IN PUEBLO OF JEMEZ



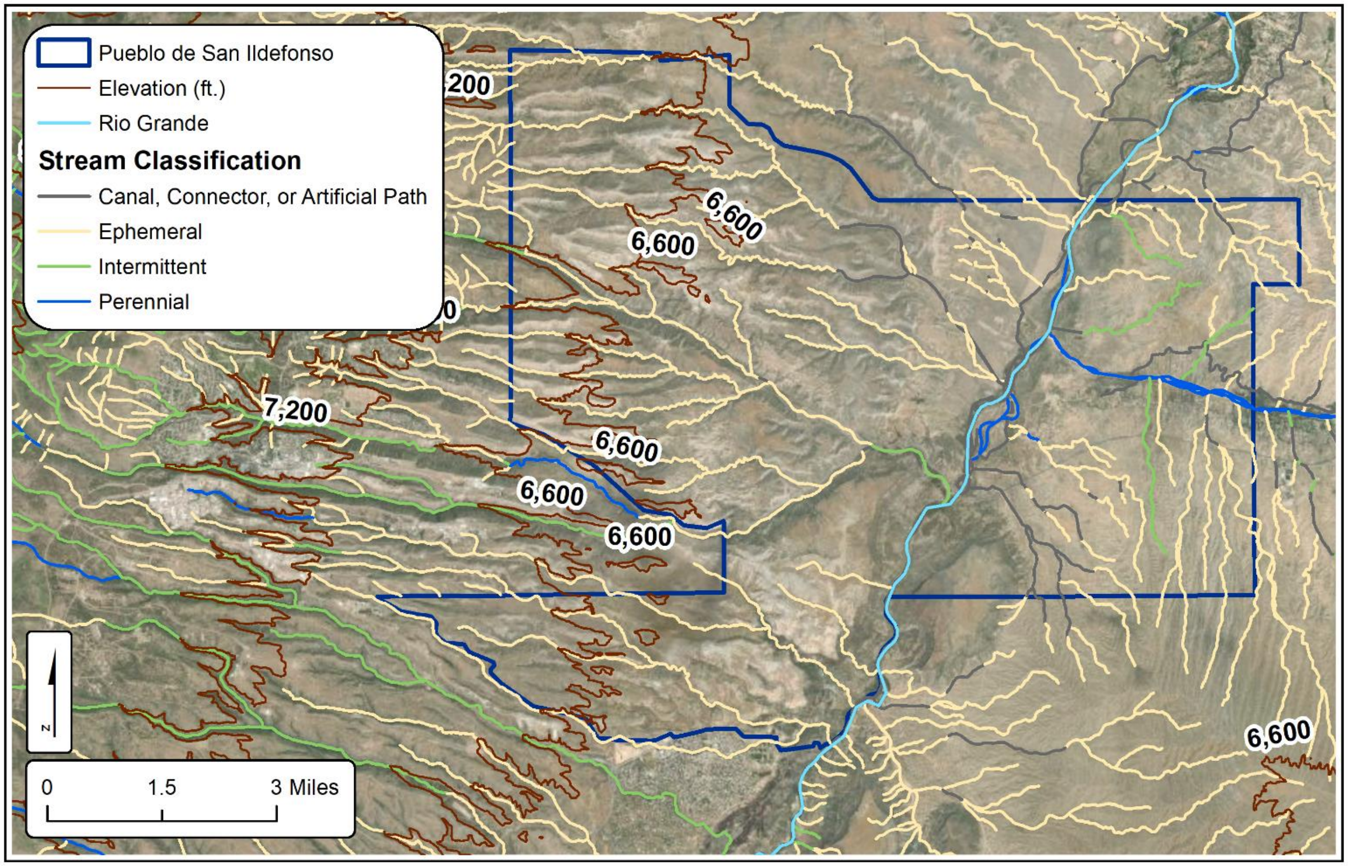
Note: Inset chosen as an example to display difference between the ERU System Type and Class.

EXHIBIT D-6. NLCD HABITAT DESIGNATIONS IN PUEBLO OF JEMEZ



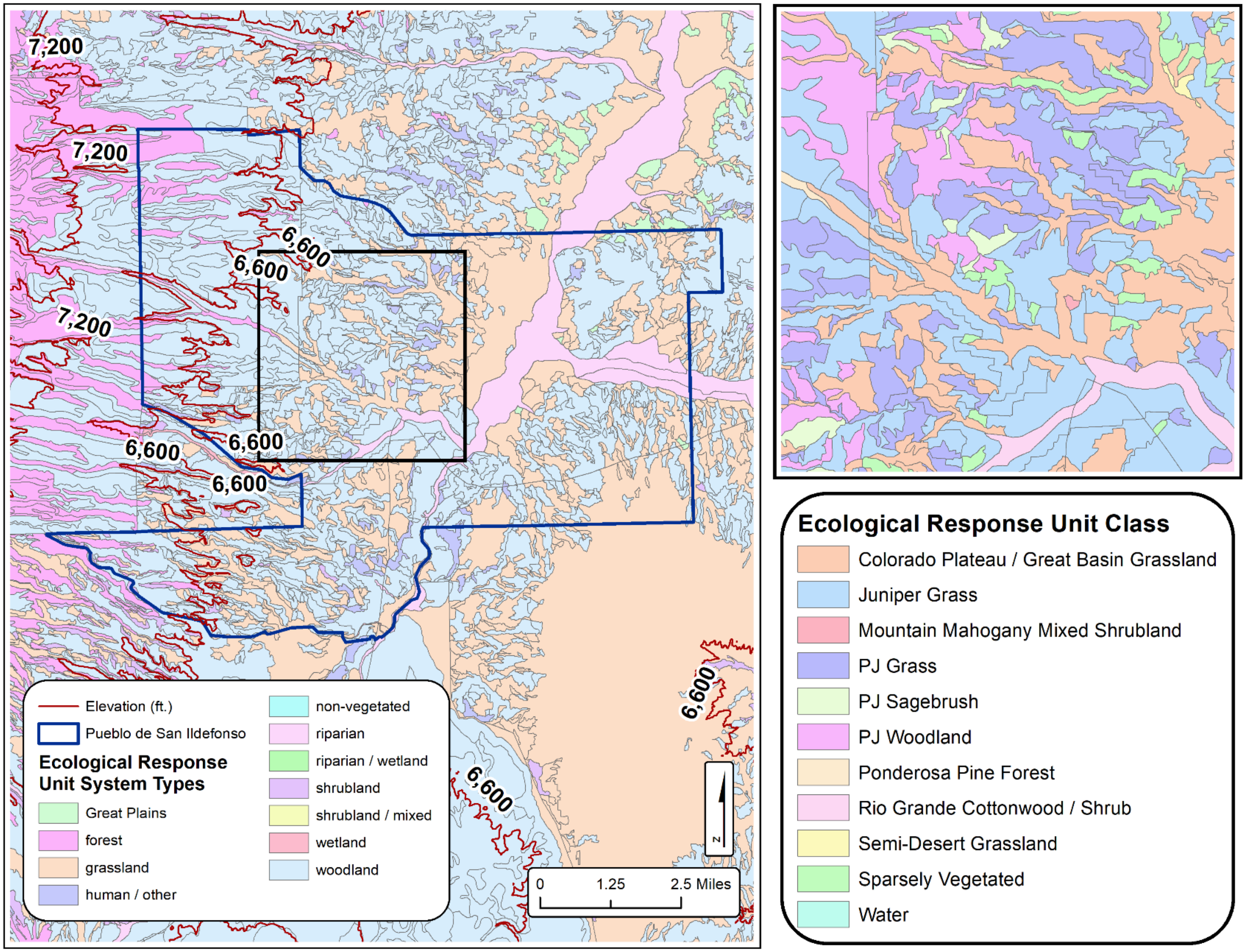
Pueblo de San Ildefonso

EXHIBIT D-7. STREAM AND ELEVATION ZONES IN PUEBLO DE SAN ILDEFONSO



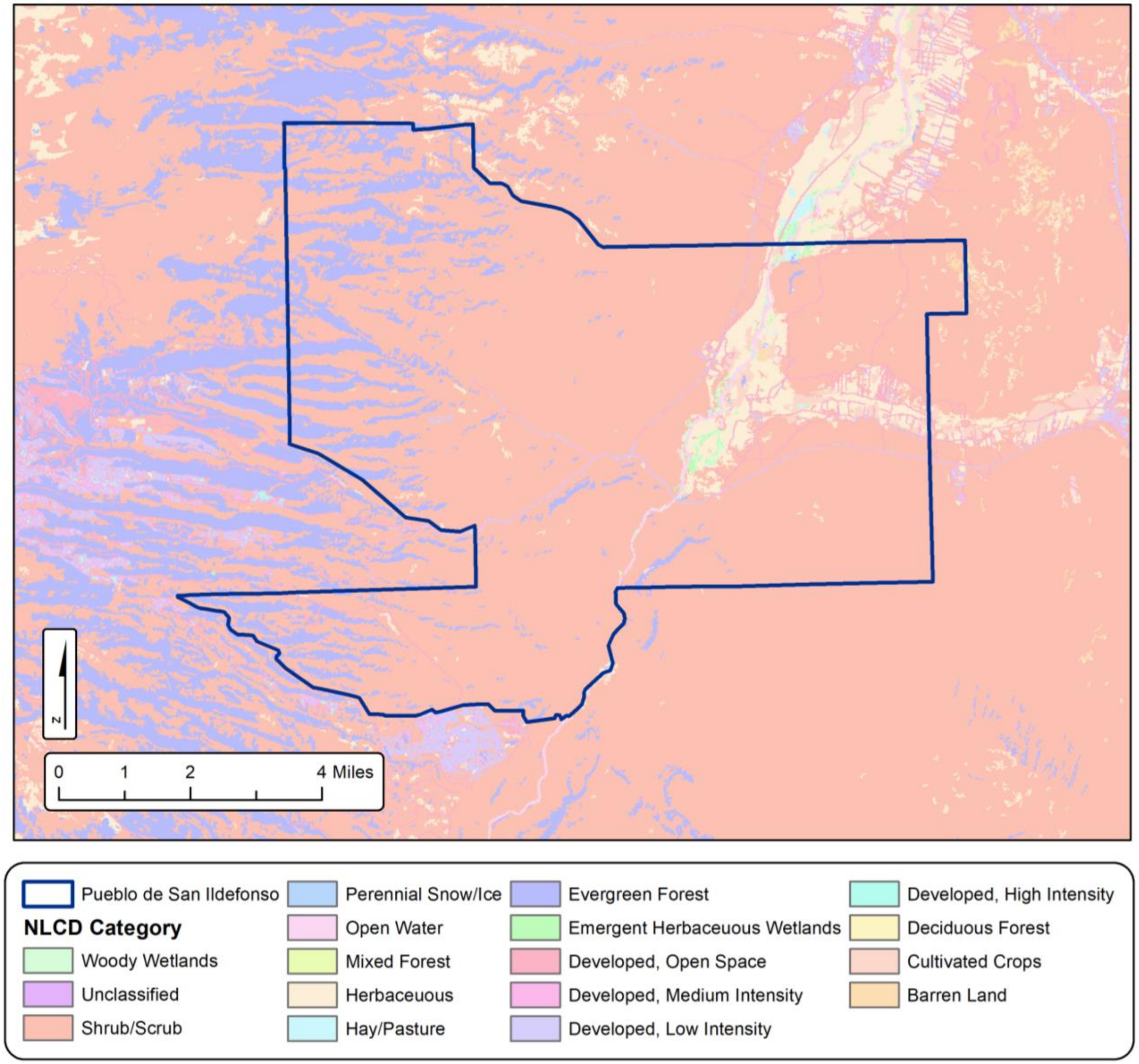
As is shown in Exhibit D-7, on Pueblo de San Ildefonso land, there are many ephemeral streams, several intermittent streams, and the perennial streams of the Rio Grande and the Pojoaque River. The map also defines the elevations throughout the Pueblo, which shows that the majority of the Pueblo lands are below 6,600 feet, with a small portion between 6,600 and 7,200 feet. These elevation zones may be used to develop associations between elevation and vegetative communities to determine the habitat types and species likely present across the assessment where site-specific survey data are not available.

EXHIBIT D-8. ERU SYSTEM TYPE AND CLASS IN PUEBLO DE SAN ILDEFONSO



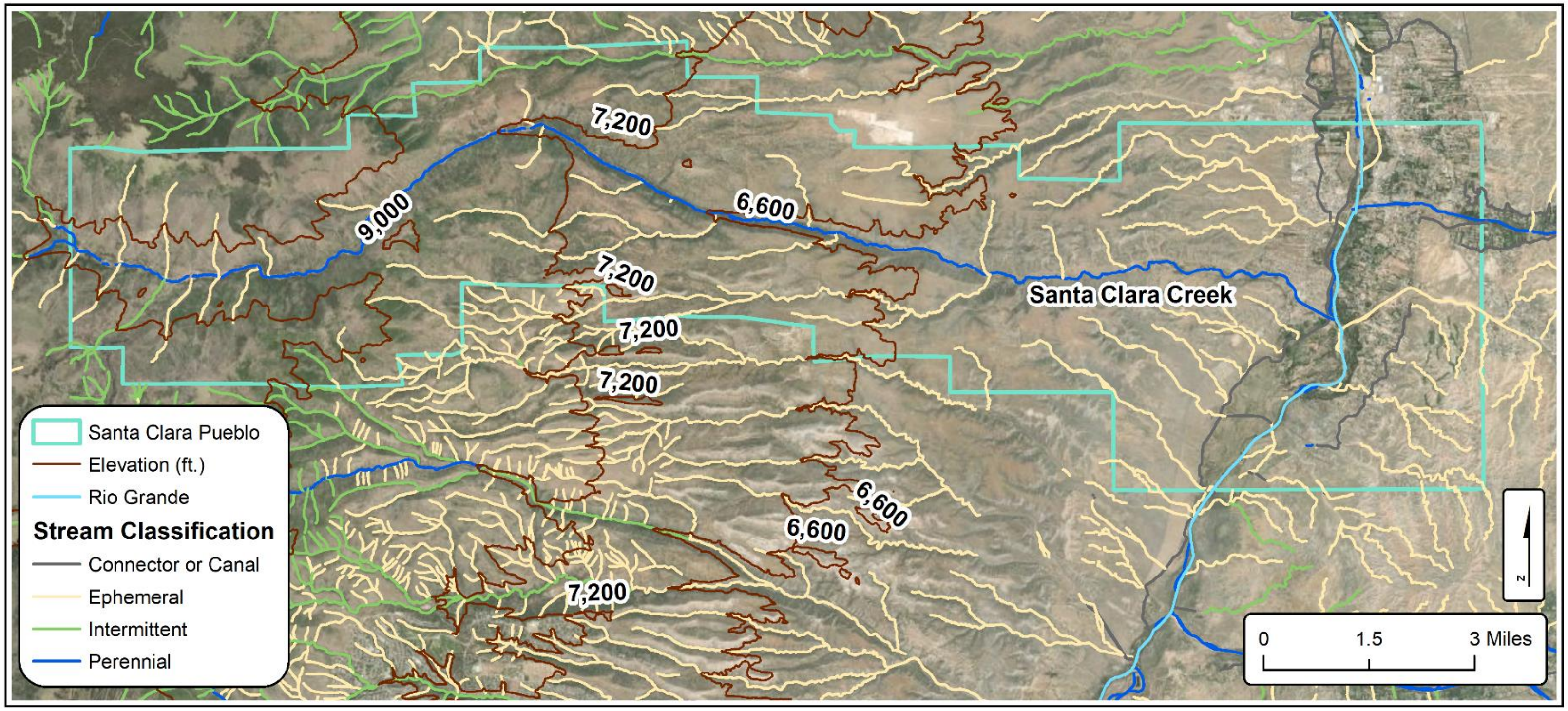
Note: Inset chosen as an example to display difference between the ERU System Type and Class.

EXHIBIT D-9. NLCD HABITAT DESIGNATIONS IN PUEBLO DE SAN ILDEFONSO



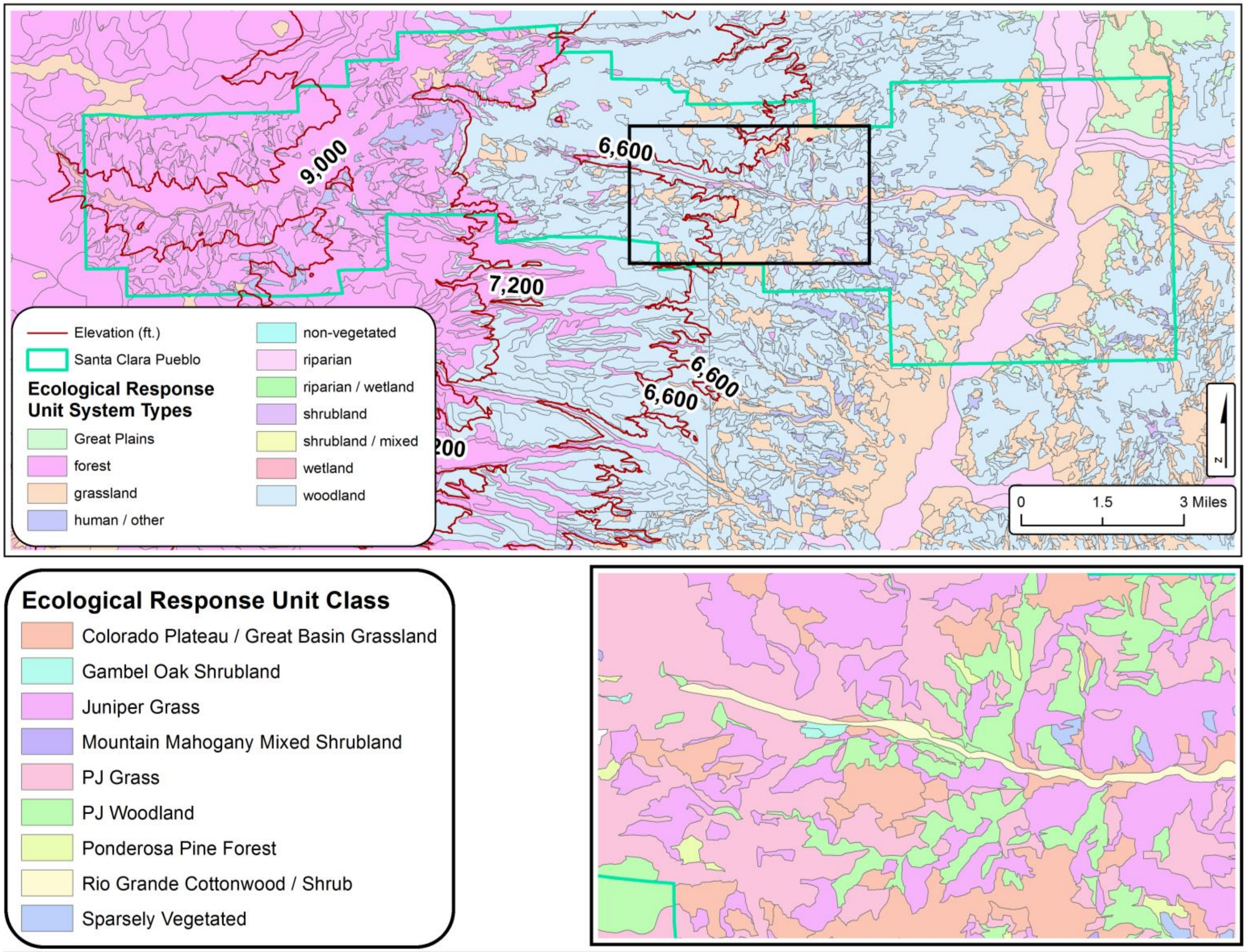
Santa Clara Pueblo

EXHIBIT D-10. STREAM AND ELEVATION ZONES IN SANTA CLARA PUEBLO



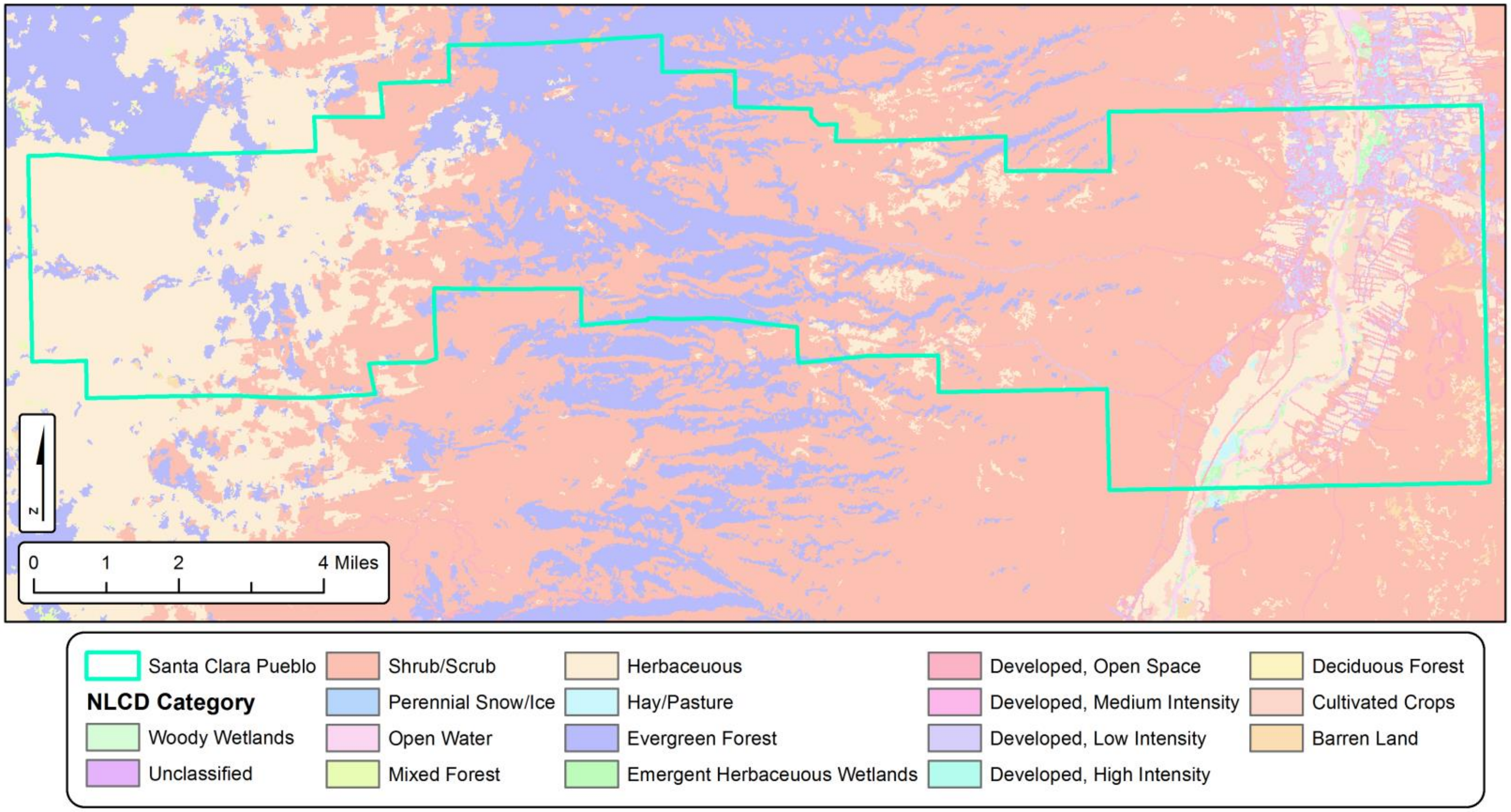
As shown in Exhibit D-10, the primary stream on Santa Clara Pueblo is Santa Clara Creek (a perennial stream) that runs through the Pueblo. There are also several ephemeral tributaries to Santa Clara Creek. Exhibit D-10 also illustrates the elevation zones throughout the Pueblo. The eastern portion of the Pueblo is below 6,600 feet in elevation and the western portion is above 7,200 feet. There is some land in the middle of the Pueblo that is in the 6,600 to 7,200 feet elevation range. These elevation zones may be used to develop associations between elevation and vegetative communities to determine the habitat types and species likely present across the assessment area where site-specific survey data are not available.

EXHIBIT D-11. ERU SYSTEM TYPE AND CLASS IN SANTA CLARA PUEBLO



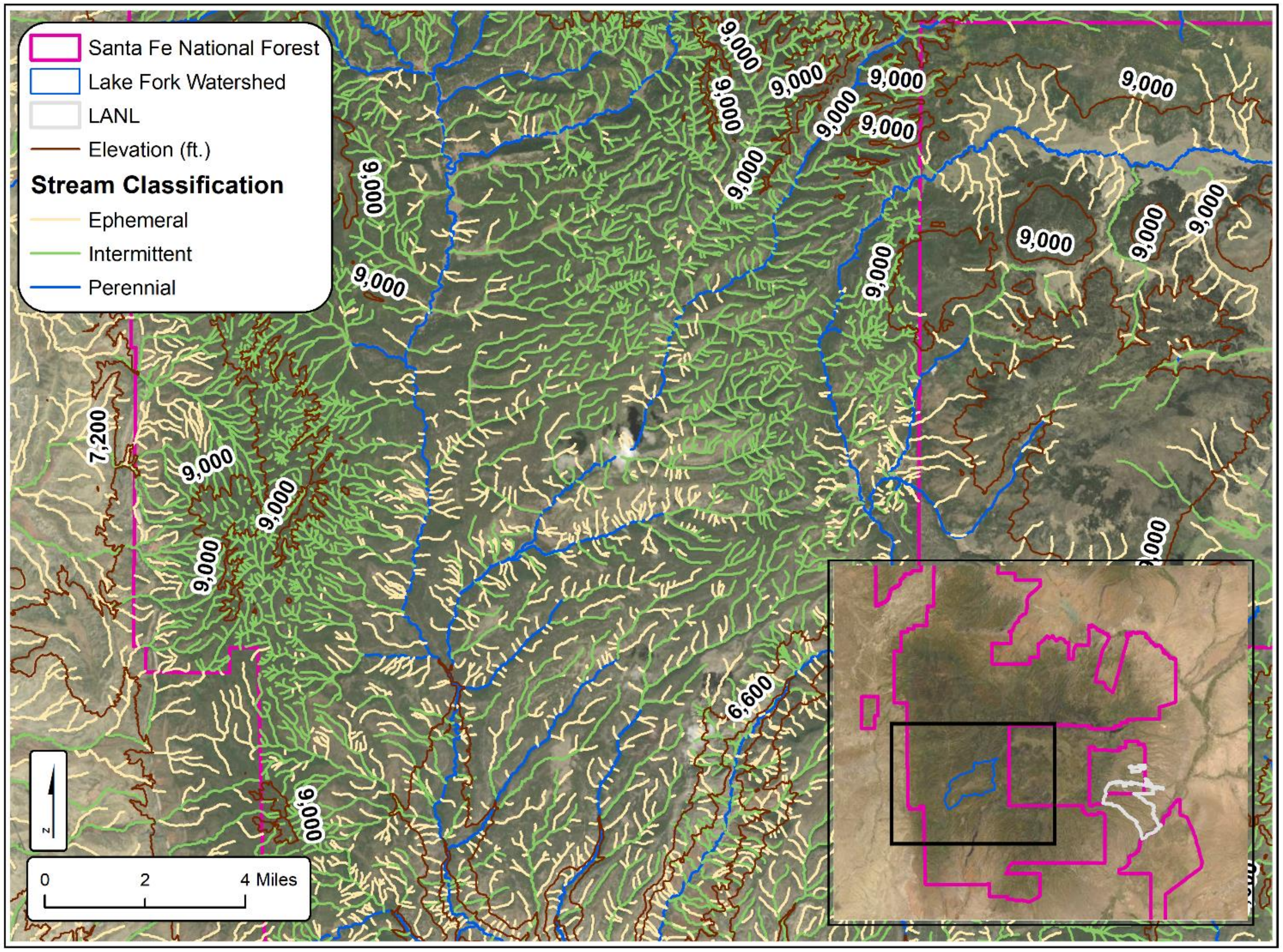
Note: Inset chosen as an example to display the differences between the ERU System Type and Class.

EXHIBIT D-12. NLCD HABITAT DESIGNATIONS IN SANTA CLARA PUEBLO



Santa Fe National Forest

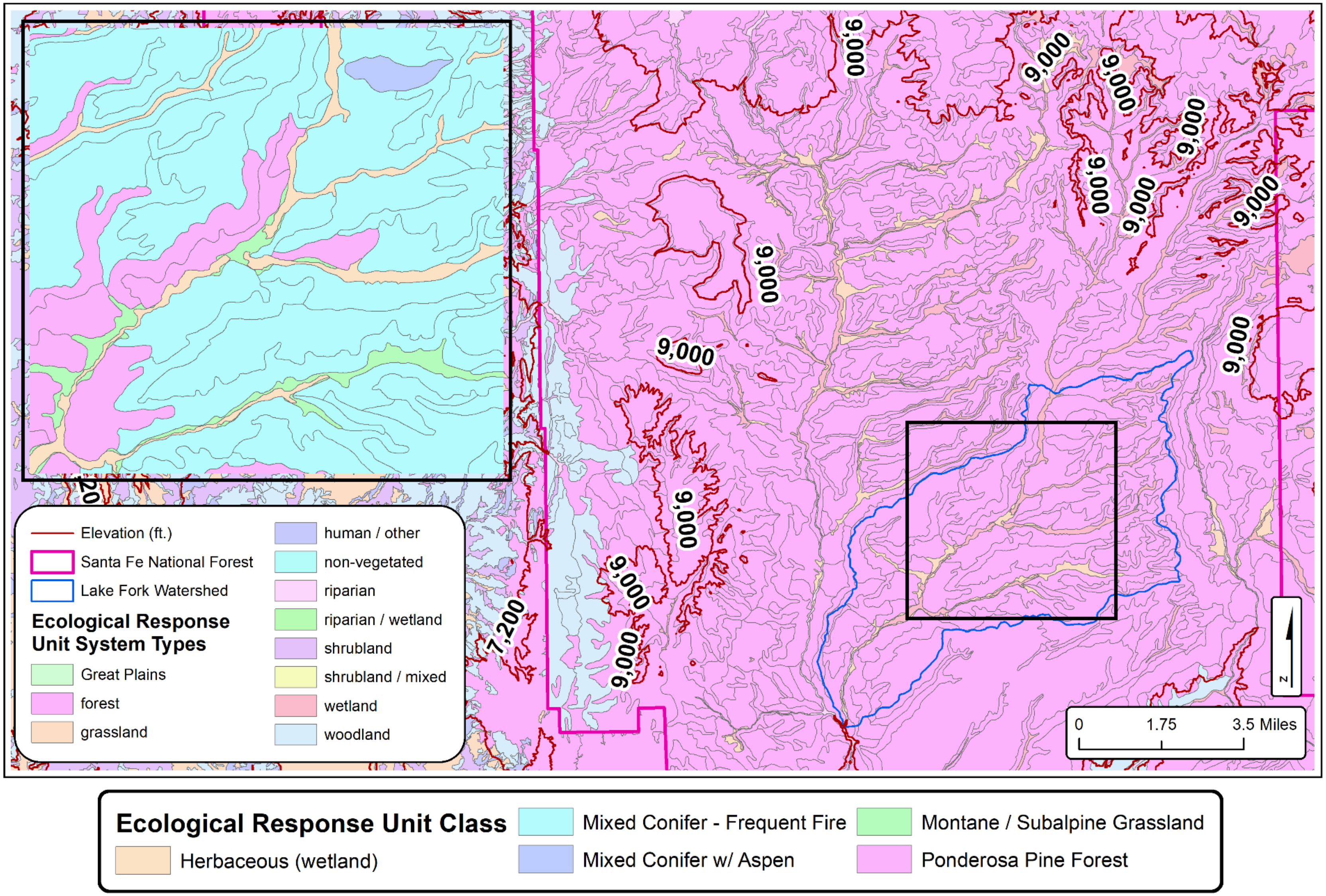
EXHIBIT D-13. STREAM AND ELEVATION ZONES IN SANTA FE NATIONAL FOREST



Note: Lake Fork Watershed displayed because there are known LANL Potential Release Sites in this watershed.

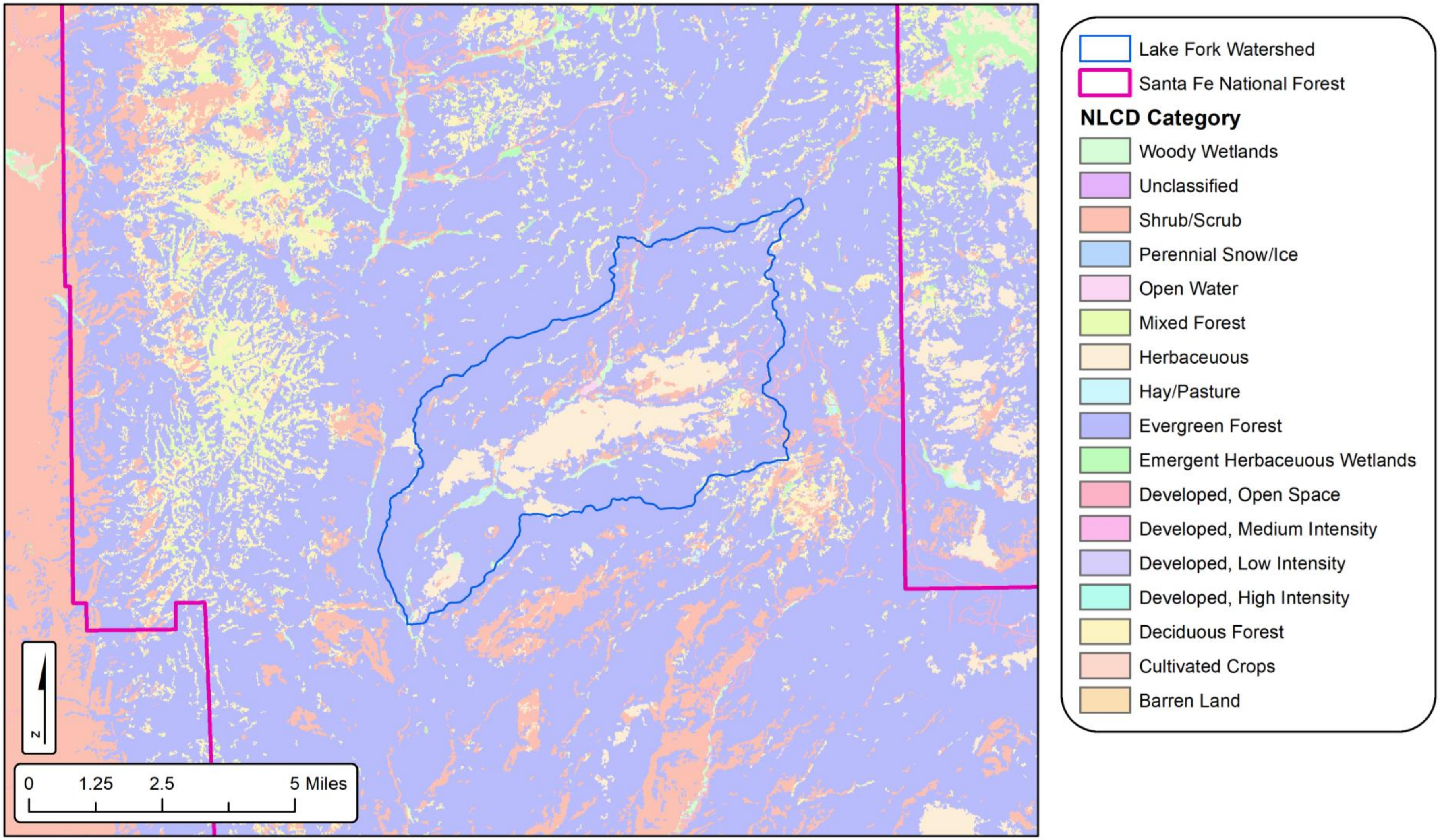
As is shown in Exhibit D-13, the Santa Fe National Forest is a large tract of land that contains many ephemeral, intermittent, and perennial streams. The map also defines the elevations throughout the area, demonstrating that the elevation largely remains constant at or over 9,000 feet. The elevation zone may be used to develop associations between elevation and vegetative communities to determine the habitat types and species likely present across the assessment where site-specific survey data are not available.

EXHIBIT D-14. ERU SYSTEM TYPE AND CLASS IN SANTA FE NATIONAL FOREST



Note: Inset chosen to highlight Lake Fork Watershed because there are known LANL Potential Release Sites in this watershed.

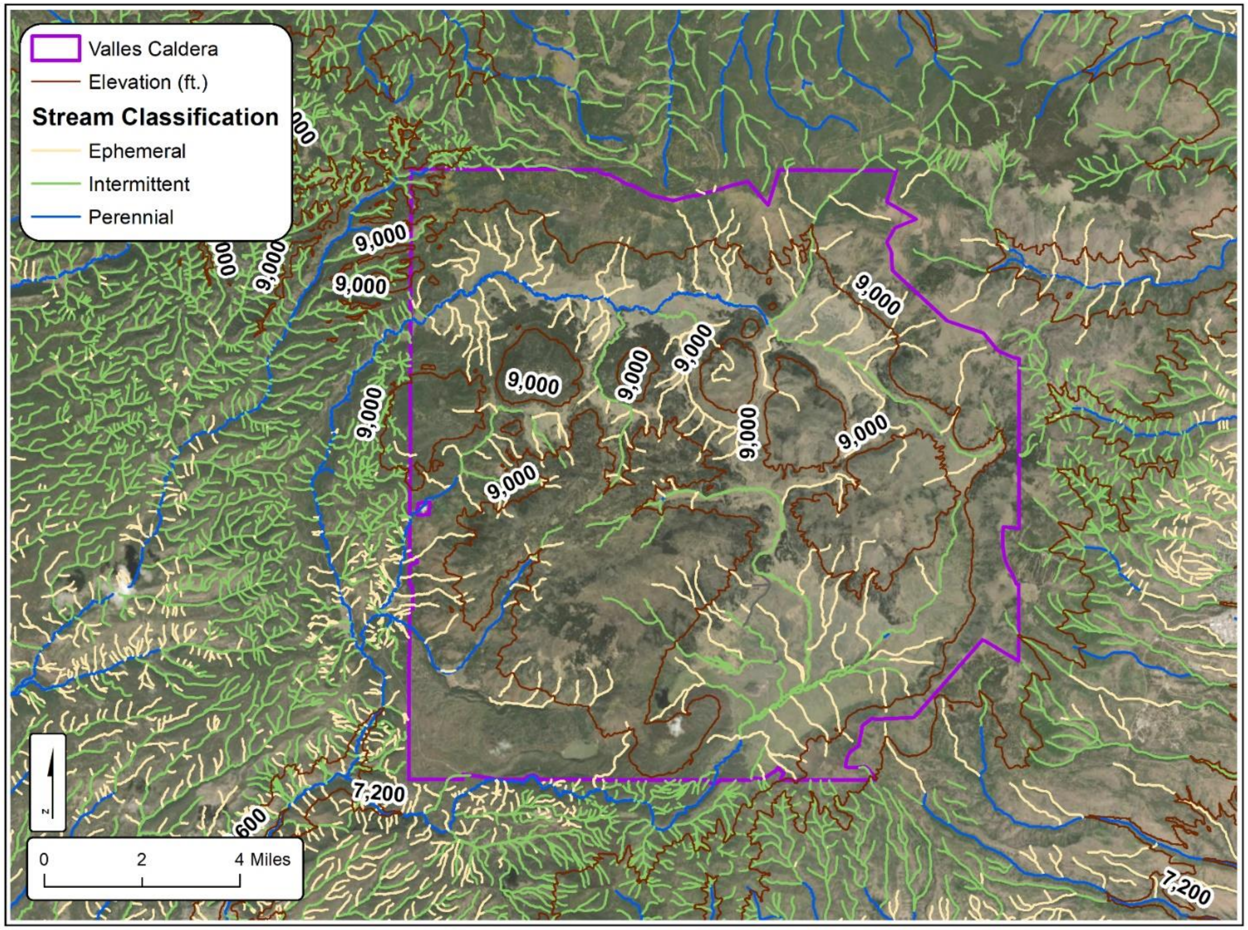
EXHIBIT D-15. NLCD HABITAT DESIGNATIONS IN SANTA FE NATIONAL FOREST



Note: Lake Fork Watershed displayed because there are known LANL Potential Release Sites in this watershed.

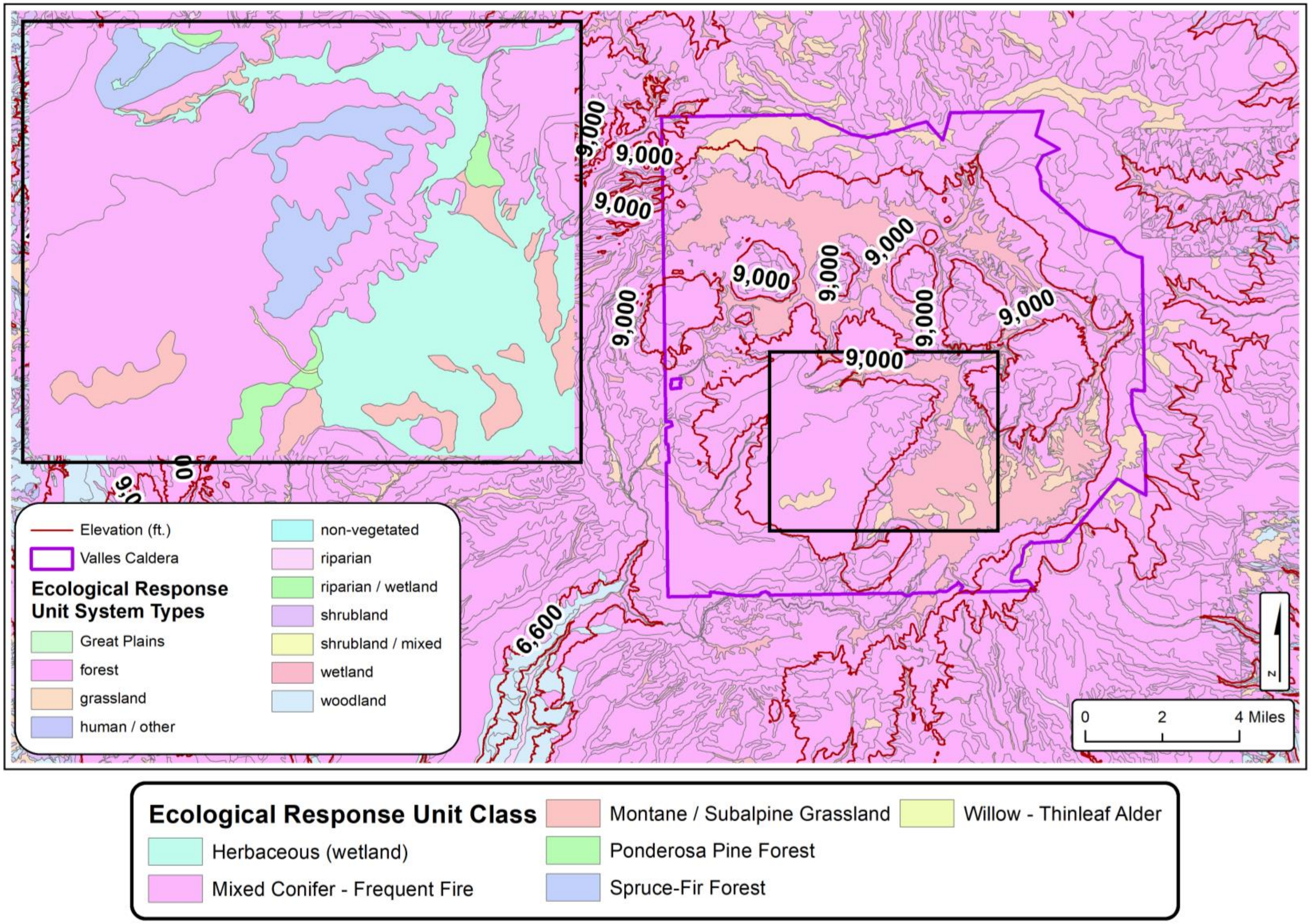
Valles Caldera National Preserve

EXHIBIT D-16. STREAM AND ELEVATION ZONES IN VALLES CALDERA



As is shown in Exhibit D-16, in Valles Caldera, there are scattered ephemeral streams, intermittent streams, and perennial streams. The map also defines the elevations throughout the area, demonstrating that the elevation remains constant at or over 9,000 feet. Only outside the southwestern corner of the caldera does the elevation drop to 7,200 feet. The 9,000 feet elevation zone may be used to develop associations between elevation and vegetative communities to determine the habitat types and species likely present across the assessment where site-specific survey data are not available.

EXHIBIT D-17. ERU SYSTEM TYPE AND CLASS IN VALLES CALDERA



Note: Inset chosen as an example to display difference between the ERU System Type and Class.

EXHIBIT D-18. NLCD HABITAT DESIGNATIONS IN VALLES CALDERA