Table of Contents

DRAFT

DRAFT

1. Introduction

The Los Alamos County Water Utility (LACWU) supplies water for Los Alamos, White Rock, Los Alamos National Laboratory (LANL), and Bandelier National Monument. To prepare for the future water supply needs of these communities, the LACWU developed a long-range water supply plan that was published in 2006 (DBS&A, 2006). This document updates that plan to incorporate more recent data and developments relevant to water resources management. The objective of this plan is to evaluate projected demands in relation to available supply, while considering water quality and water rights risks to the supply, to ultimately ensure that both a viable physical supply and associated water rights are in place as needed to meet future demands.

In addition to providing a plan for a sustainable future water supply, a long-range water plan that covers at least 40 years addresses several regulatory requirements regarding water rights and water conservation. In particular, a water plan allows certain organizations, including Counties, to set aside water for use in the future. Section 72-1-9(B) of the New Mexico Water Code allows covered entities such as Los Alamos County to legally appropriate and preserve water that they cannot currently use but will need in the future to meet projected water requirements for the service area based on projected growth and other factors. Counties are specifically exempt from forfeiture of unused water rights if those rights have been appropriated for the implementation of a water development plan or for preservation of water supplies (NMSA 72-12-8 (F)). These provisions are the same for both surface water and groundwater (NMSA 72-5-28(C)).

The New Mexico Office of the State Engineer (OSE) requirements set out in statute NMSA 1978 Section 72-14-3.2 call for conservation planning by any public supply system with diversions of at least 500 acre-feet annually for domestic, commercial, industrial, or government customers for other than agricultural purposes. Covered entities must develop, adopt, and submit to the OSE a comprehensive water conservation plan, including a drought management plan, as a prerequisite for applying for funding from key state funding agencies. The Water Trust Board requires funding applicants to provide verification from the OSE that all of its statutory and regulatory requirements have been met, and the OSE is requiring that Water Trust Board funding applicants have a conservation plan that was prepared in accordance with New Mexico's *Water Conservation Planning Guide for Public Water Suppliers* (NMOSE, 2013). The U.S. Bureau of Reclamation (USBR) also requires a conservation plan for diversion of San Juan-Chama Project water.

The LACWU published an *Energy and Water Conservation Plan* in 2013 (LACWU, 2013a) and updated it in 2015 (LACWU, 2015), and prepares reports annually discussing the County's progress toward the goals established in that plan. This long-range water supply plan summarizes the water conservation goals established by the *Energy and Water Conservation Plan* and provides an update on its implementation and recommendations.

For this long-range water supply plan, the LACWU retained Daniel B. Stephens & Associates, Inc. (DBS&A) to update the 2006 plan with current data and analyses. The remainder of this water plan presents the results of the summarized and updated information including an overview of the water system (Section 2), water supply and water rights (Sections 3 and 4), current and projected demand and supply-demand gaps (Sections 5 and 6), risks due to climate change (Section 7), water conservation (Section 8), and actions the LACWU may undertake to plan for a sustainable future water supply (Section 9).

2. Overview of Los Alamos County Water System

The Los Alamos Boys Ranch, a school for teenage boys started in 1918, was the original settlement in the area that is now Los Alamos County. The sole source of water for the school was surface water from Los Alamos Reservoir in Los Alamos Canyon (Figure 2-1). The water was piped from the reservoir and stored in a redwood water tank near the school. During World War II, Los Alamos was selected as the site for the secret Project Y, because the steep canyons and mesa tops provided a secure location for the project. The Los Alamos Laboratory (as it was then called) came into existence in early 1943 for the single purpose of Project Y: to design and build an atomic bomb (LANL, 2006). Los Alamos Boys Ranch closed in early 1943 and the Laboratory became the only establishment. In 1949, Los Alamos County was created from parts of Sandoval and Santa Fe Counties.

When the Laboratory took over in 1943, they continued to use Los Alamos Reservoir, but also piped in water from a spring gallery in Guaje Canyon. In 1947, a dam was built in Guaje Canyon and water from the resulting Guaje Reservoir was used for water supply (Figure 2-1). In addition, American Spring and several springs in Water Canyon were tapped and piped into the water system. The Los Alamos well field was drilled in 1946 on San Ildefonso Pueblo property, thereby increasing the supply to meet the growing demands of the Laboratory and its residents. By 1989, groundwater from the Los Alamos, Guaje, Pajarito, and Otowi well fields supplied all of the potable demands for Los Alamos.

The Los Alamos well field was plugged and abandoned in 1992 because the wells had reached the end of their useful life. Also in the 1990s, six of the seven wells in the Guaje well field were retired, and four replacement wells were drilled and tapped into the existing piping and booster stations. Los Alamos Reservoir continued to be used to water parks, but the Cerro Grande fire in 2000, Las Conchas fire in 2011, and subsequent flooding in 2012, 2013, and 2014 damaged the reservoir and the diversion system. The LACWU has been working on a water line replacement project in order to bring the reservoir back online. The reservoir has been dredged and the LACWU will be installing a new pipeline from the reservoir into town in order to connect to the existing non-potable infrastructure (Meyers, 2016). The LACWU is also in the process of completing a few other non-potable projects, including installing booster pumps and pipelines to push non-potable water to the Group 12 tank, which has been renovated. This will allow gravity feed of the non-potable water to all current users, including the golf course and ball fields (Meyers, 2016).

The LACWU began operating the water system in September 1998; however, ownership of the water system and water rights was not transferred from the U.S. Department of Energy (DOE) to the LACWU until September 2001 (ownership of 70 percent of the water rights was transferred to Los Alamos County and DOE retained the other 30 percent). The LACWU ~~currently~~ provides water service to the residents of Los Alamos and White Rock, LANL, and Bandelier National Monument. The LACWU has a contract to supply DOE with the water required by LANL with no limitations. This contract will expire in 2019 (LANL demands have been projected beyond 2019 under the assumption that a new contract will be negotiated).

The LACWU has a contract with the U.S. Bureau of Reclamation for water from the San Juan-Chama Project, which brings water from the San Juan Basin to Heron Reservoir on the Rio Chama (the Rio Grande Basin). Releases from Heron Reservoir flow down the Rio Chama to the Rio Grande. In the *San Juan-Chama Water Supply Project Final Preliminary Engineering Report,* the recommended alternative for the LACWU to obtain and treat San Juan-Chama Project water for distribution was to construct up to three groundwater wells in the White Rock area and install pumps and a pipeline to connect the new wells to the Pajarito Booster Station (CDM Smith, 2012); however, the alternatives and project timeline will be revisited after the long-range water supply plan update is complete. The diversion rights of San Juan-Chama **Project** water could alternatively be used to offset impacts of pumping (as the City of Santa Fe has done since 1972), as further discussed in Sections 4.3.2 and 6.

With the abandonment of the Los Alamos well field and six wells in the Guaje well field, the LACWU water system is currently supplied by the 12 wells shown in Figure 2-1 and listed in Table 2-1. These wells, with depths up to 3,000 feet below ground surface (ft bgs) and water levels ranging from approximately 250 to 1,200 ft bgs, all draw on the regional aquifer beneath the Pajarito Plateau.

Table 2-1. Active Wells in the Los Alamos Water Supply System.

Well Field	Well Name	Date Completed	Completion Depth (feet)	Coordinates (feet)		Initial Depth to Water
				x	Y	
Guaje	G-1A	Oct-54	1,519	1,655,241	1,784,353	250
	G-2A	Mar-98	1,980	1,651,974	1,786,166	318
	G-3A	May-98	1,980	1,649,662	1,786,585	408
	G-4A	Apr-98	1,980	1,647,318	1,787,113	452
	G-5A	Jun-98	1,980	1,644,877	1,789,636	551
Otowi	O-1 [a]	Aug-90	2,497	1,649,396	1,772,232	673
	O-4	Mar-90	2,595	1,637,337	1,772,995	780
Pajarito	PM-1	Feb-65	2,499	1,647,734	1,768,112	722
	PM-2	Jul-65	2,300	1,636,698	1,760,406	823
	PM-3	Nov-66	2,552	1,642,590	1,769,530	740
	PM-4	Aug-81	2,874	1,635,623	1,764,740	1,060
	PM-5	Sep-82	3,092	1,632,110	1,767,790	1,208

Source: Koch and Rogers, 2003

[a] Well is currently not being used to supply drinking water.

Two new applications have been filed recently:

- The LACWU filed an application for an additional point of diversion on April 28, 2016. The new well will be called Otowi Well 2 and will be drilled to supplement the system's existing production wells in anticipation of declining production rates from existing wells that are nearing the end of their service life (Alarid, 2016).

- In May 2016, an application for permit to change an existing water right was filed jointly by DOE and the LACWU in support of the chromium plume control interim measure and chromium plume center characterization project (U.S. DOE and LACWU, 2016), and emergency authorization was received on September 10, 2016 (NMOSE, 2016).

The addition of new points of diversion under these applications will not increase the appropriation of water above the existing permitted water rights.

Wastewater is treated at two facilities: the White Rock wastewater treatment plant (WWTP) and the Los Alamos WWTP. Both of these WWTPs have treated effluent reuse lines that are used for irrigation of turf. Two former WWTPs—the East Road, abandoned and demolished in the mid-1960s, and the Pueblo, abandoned in 1993—also had effluent reuse systems, both of which supplied the golf course.

The LACWU operates a non-potable water system, using treated wastewater effluent to irrigate several areas in Los Alamos and White Rock and using stormwater runoff for fire protection and snow making at the Pajarito Mountain Ski Area (Forsgren & Associates, 2013). The system has three separate components:

- *Los Alamos Townsite:* Reuse is used to irrigate four sites in Los Alamos (Los Alamos County Golf Course, Los Alamos Middle School, North Mesa Ball Fields, and North Mesa Soccer Fields) and to feed the wetlands located downgradient of the Los Alamos wastewater treatment facility. A volume of 180,000 gallons per day is needed to keep the wetlands healthy. LANL is currently receiving reuse water for the wetlands from the LACWU at no charge because surplus reuse water is available.

- *White Rock:* Reuse is used to irrigate Overlook Park.

- *Pajarito Mountain Ski Area:* Captured stormwater is used for fire protection and snow making.

A Los Alamos County non-potable water system master plan was completed in 2013, to evaluate the efficiency of the existing non-potable water system, make recommendations for how to improve the system's efficiency, determine if additional development of non-potable water use is economically feasible, and identify and evaluate sites that could potentially be served (Forsgren & Associates, 2013), most of which currently use potable water for irrigation. The plan identified a total of 25 sites (5 existing and 20 new) suitable for service by the Los Alamos Townsite non-potable water system and 6 sites (1 existing and 5 new) for the White Rock non-potable water system. Bringing the additional sites online would increase the annual average system demands from 152.8 to 206.5 million gallons per year for the Los Alamos

Townsite system and from 18.9 to 41.2 million gallons per year for the White Rock system (Forsgren & Associates, 2013).

3. Hydrologic Overview and Risks to Water Supply

The LACWU public drinking water supply is supplied by groundwater, with surface water supplying a small amount of non-potable use. This section describes the hydrogeologic conditions pertinent to the Los Alamos groundwater supply (Section 3.1) and includes an assessment of potential risks to the groundwater supply due to depletion or contamination of the aquifer (Section 3.2). The LACWU water rights (groundwater and surface water) are discussed in Section 4.

3.1 Hydrogeology

Los Alamos County is situated on the Pajarito Plateau within the western side of the Española Basin. The Pajarito Plateau extends eastward from the Sierra de los Valles, the eastern range of the Jemez Mountains. On the western part of the Pajarito Plateau, the Bandelier Tuff overlaps the Tschicoma Formation, which consists of older volcanics that form the Jemez Mountains. In the central Pajarito Plateau and near the Rio Grande, the Bandelier Tuff is underlain by the Puye Formation. The Cerros del Rio basalts interfinger with the Puye Formation conglomerate along the river and extend beneath the Bandelier Tuff to the west. These formations overlie the sediments of the Santa Fe Group, which extend across the basin between LANL and the Sangre de Cristo Mountains and are more than 3,300 ft thick (LANL, 2014a). A cross section of the area is shown on Figure 3-1.

The hydrogeologic framework within Los Alamos County consists of three distinct aquifer systems **(LANL, 2014a)**:

- Shallow perched groundwater in alluvial deposits along canyon bottoms
- Intermediate-depth perched groundwater
- Deeper regional aquifer, which extends through the neighboring Española Basin ~~(LANL, 2014a)~~

DRAFT

A block diagram depicting a conceptual model of the hydrogeology of the Los Alamos area that illustrates the general configuration of these aquifer systems is shown in Figure 3-2.

Alluvial aquifers occur within axial fluvial deposits located along canyon bottoms and have a limited saturated thickness and variable lateral extent, depending on the presence of intermittent surface flow or anthropogenic discharges from wastewater treatment outfalls. Hydrologic investigations of alluvial aquifers have been conducted in Los Alamos Canyon, Pueblo Canyon, Mortandad Canyon, Pajarito Canyon, Sandia Canyon, Cañon de Valle, and Water Canyon. Though their limited extent precludes any utility for beneficial use, these aquifers provide an important pathway for contaminant migration.

Intermediate-depth perched aquifers are widely distributed across the northern, western, and central parts of the Pajarito Plateau beneath Los Alamos Canyon, Pueblo Canyon, Sandia Canyon, Mortandad Canyon, and Cañon de Valle. These perched zones usually occur in the Puye Formation fanglomerates, the Cerros del Rio Basalt, and units of the Bandelier Tuff, and are typically associated with low-permeability layers such as unfractured basalt flows and fine-grained zones. Saturated thicknesses range from about 3 to 420 feet, but lateral extents are sometimes poorly defined (LANL, 2005). Depths to the intermediate perched groundwater vary. For example, the depth to intermediate-perched groundwater is approximately 120 feet in Pueblo Canyon, 450 feet in Sandia Canyon, and 500 to 750 feet in Mortandad Canyon (LANL, 2014a). Though the exact extent of these aquifers is not well defined, it is clear that they are generally small enough that their potential for beneficial use is limited. However, they provide an important pathway for contaminant migration through the vadose zone.

The regional aquifer occurs primarily within the poorly to semi-consolidated basin-fill sediments of the Santa Fe Group. The total thickness of the Santa Fe Group beneath the Pajarito Plateau is poorly defined. The deepest well on the plateau (PM-5), with a depth of 3,110 feet, does not fully penetrate the base of the basin-fill sediments. Estimates of the total thickness of these sediments range from 6,650 feet in the central basin to as much as 9,000 to 10,000 feet in the central and western parts of the basin (Broxton and Vaniman, 2005).

The regional aquifer extends into the overlying Puye Formation fanglomerate beneath parts of the Pajarito Plateau. Other geologic units encompassed by the regional aquifer beneath parts of the county include fractured volcanic rocks of the Tschicoma Formation (western part) and the Cerros del Rio Basalt (eastern part), as well as localized occurrences of older basalts.

The regional aquifer water table occurs at a depth of 1,200 feet along the western edge of the plateau and 600 feet along the eastern edge. In the central part of the plateau, the regional aquifer lies about 1,000 feet beneath the mesa tops. The regional aquifer is the only aquifer in the area capable of serving as a municipal water supply (LANL, 2014a).

Well locations and types are shown in Figure 3-3, and the potentiometric surface contours and extrapolated flow directions in the regional aquifer are shown in Figure 3-4. Water in the regional aquifer generally flows east or southeast (LANL, 2015c). As discussed in Section 2, the LACWU's production wells have water levels that range between approximately 250 and 1,200 feet below ground surface (ft bgs). Water in the regional aquifer is under artesian conditions beneath the eastern part of the Pajarito Plateau near the Rio Grande and under phreatic conditions beneath most of the Pajarito Plateau (Purtymun and Johansen, 1974). The upper portion of the regional aquifer beneath the Laboratory discharges into the Rio Grande through springs in White Rock Canyon (LANL, 2014a).

Groundwater modeling studies indicate that underflow of groundwater from the Sierra de los Valles west of Los Alamos is the main source of regional aquifer recharge (LANL, 2014a). Alluvial groundwater is also a source of recharge to the regional aquifer, as well as to the intermediate perched saturated zones (thereby providing potential downward pathways for contaminants released at the surface to eventually reach the regional aquifer).

A number of studies have estimated recharge to the regional aquifer for the Española Basin and for the Pajarito Plateau (Table 3-1). Recharge varies in relation to precipitation, which in Los Alamos County is elevation-dependent and ranges between about 13 and 20 inches annually (Newman and Robinson, 2005). Keating et al. (2005) determined that significant recharge occurs primarily above the 2,195-meter (7,200-foot) elevation. At lower elevations, recharge occurs primarily in canyons and arroyos; recharge on mesas is minimal to non-existent

(Anderholm, 1994; Birdsell et al., 2005). Kwicklis et al. (2005) estimated that 23 percent of total recharge to the regional aquifer beneath the plateau is from streamflow loss.

In addition to the recharge estimates, Table 3-1 includes an estimate of discharge to the Rio Grande (determined from inverse modeling using streamflow data and transient head data), which approximates aquifer recharge before significant pumping began.

Table 3-1. Regional Aquifer Recharge Estimates

Category	Rate (ac-ft/yr)	Source
Pajarito Plateau recharge	8,596	Kwicklis et al., 2005
	4,912	McLin et al., 1996
	4,298 to 5,526	Griggs and Hem, 1964
	8,084	Hearne, 1985
Lateral inflow from Jemez Mountains	7,445	McAda and Wasiolek, 1988
Discharge to Rio Grande from Pajarito Plateau and Sierra de los Valles	6,473	Keating et al., 2003

~~A number of investigations have been conducted to help understand regional aquifer properties as they relate to the potential for contaminant transport:~~

- ~~The results of pump tests performed in several regional aquifer monitor wells (often referred to as *R-* wells) installed as part of LANL's *Hydrogeologic Work Plan* (1998) implementation showed hydraulic conductivities ranging from 0.04-4.9 feet per day (ft/d) in all wells except R-13, which had a much higher conductivity (DBS&A, 2006).~~

- ~~A multiple well pump test conducted by LANL on supply well PM-2 during February 2003, using supply wells PM-4 and PM-5 (which were not pumped during the 25-day test) and monitor wells R-15, R-20, R-21, R-22, and R-32 as observation wells (McLin, 2005), estimated hydraulic conductivities ranging from 5 to 15 ft/d (DBS&A, 2006).~~

- ~~Anisotropy, the ratio of vertical to horizontal hydraulic conductivity, is important for predicting contaminant movement in the vadose and saturated zones. Pumping test~~

~~analyses have indicated that a strong degree of anisotropy is present in the regional aquifer beneath the Pajarito Plateau. Hydrologic modeling suggests that vertical permeability is 100 to 1,000 times lower than horizontal permeability in the Santa Fe Group silts and sands (Hearne, 1985; McAda and Wasiolek, 1988; Keating et al., 2003, as cited by LANL, 2005), indicating that contamination is much more likely to move horizontally than vertically.~~

- ~~A 2008 aquifer test evaluated responses in monitor wells R-11, R-15, and R-28 due to long-term water supply pumping at the Pajarito (PM-1 through PM-5) and Otowi (O-1 and O-4) well fields, and concluded that there is considerable heterogeneity in aquifer properties. The heterogeneity can lead to preferential flow paths (Vesselinov et al., 2008).~~

- ~~The deep section of the regional aquifer pumped by Santa Fe's Buckman well field is in relatively poor hydraulic connection with the Rio Grande and the aquifer below LANL. This can be explained by the pronounced westward-dipping stratification of the Santa Fe group sediments near the Buckman well field, which cause the aquifer to be anisotropic and under confined conditions (Vesselinov et al., 2011).~~

3.2 Aquifer Depletion Risk

To evaluate risks of water supply depletion, available water level data from numerous wells screened in the regional aquifer were used to plot hydrographs illustrating historical water level behavior in the regional aquifer. Locations of these wells are shown in Figure 3-3. Long-term supply well data, consisting of annual average non-pumping water levels for the Guaje well field (since 1950) and the Pajarito well field (since 1965), are shown in Figures 3-5 and 3-6 respectively. More recent (since 1990) but sporadic data are available for the Otowi well field (Figure 3-7).

Table 3-2 summarizes the net changes and average water level declines indicated by these data. Long-term data from the Pajarito and Guaje well fields indicate an average water level decline of about 1.1 and 3.5 feet per year (ft/yr), respectively; the average decline in the Otowi

DRAFT

well field is about 0.8 ft/yr. Substantial declines have occurred in the abandoned Guaje wells, ranging from about 0.2 to 2.5 feet, and averaging about 1.3 ft/yr.

LANL also monitors water levels in regional wells. Previous analysis of those data indicated that responses were mixed but that water levels in most regional wells were also steadily declining (DBS&A, 2006). Though the average rate of decline appears modest on an annual basis, one supply well has experienced a total water level decline of approximately 85 feet since 1998, and water levels in four of the active production wells have declined by more than 50 feet (Table 3-2).

Using water level data, Rogers et al. (1996) estimated the volume of groundwater depletion from supply well production between 1949 and 1993 to be between 4.0×10^{10} and 6.0×10^{10} gallons (123,000 and 184,000 acre-feet), compared to total pumping withdrawals of 5.7×10^{10} gallons (175,000 acre-feet) during the same period. This analysis implies that recharge to the regional aquifer during this period was negligible and that production well pumping was essentially mining the aquifer. However, the recovery of water levels in wells that were not pumped for extended periods was cited by McLin et al. (1996) as evidence that recharge has occurred. Water levels can recover without recharge as the cone of depression that develops during pumping re-equilibrates, however, and it should be noted that the recharge estimates presented in Table 3-1 are on the same order as pumping withdrawals.

Even if net recharge is negligible, considering a demonstrated saturated thickness of at least 1,900 feet penetrated in supply well PM-5 and potentially as much as 10,000 feet of Santa Fe Group sediments underlying the plateau (Section 3.1), a continuation of the observed rates of decline does not represent a substantial imminent or foreseeable risk to the water supply. Barring potential water quality issues, continued pumping of the regional aquifer at current rates is likely to be sustainable for hundreds of years. LANL's Española Basin and Pajarito Plateau Regional Flow Model predicts that water levels will continue to decline at the same rate (with the same production rates) and that this rate can be sustained for hundreds of years (Keating, 2006). However, the water is expected to be of poorer quality as wells begin to draw from greater depths, and pumping costs will increase.

3.3 Contamination Risk

To evaluate the potential for the LACWU water system to produce water quality that meets all drinking water standards, this section (1) identifies sources of contaminants in the Los Alamos area, (2) summarizes existing knowledge of contaminant transport pathways and velocities, **and** (3) summarizes the concentrations and extent of chromium, perchlorate, and other contaminants in groundwater~~, and (4) discusses potential treatment options~~.

3.3.1 Sources of Contamination

Since the early 1940s, a wide array of chemicals have been released into the canyons of the Pajarito Plateau from various LANL operations. These releases have occurred through effluent discharges from wastewater treatment facilities and other miscellaneous sources, such as sanitary septic systems, cooling towers, and runoff from firing sites and other LANL facilities. Figure 3-8 shows the locations of industrial outfall sites at LANL.

The presence of contaminants in groundwater in Los Alamos County is primarily associated with areas where effluent discharges have led to enhanced infiltration. Since the 1940s, liquid effluent discharge by LANL has affected the shallow perched alluvial groundwater that lies beneath the floor of a few canyons, and has also affected intermediate-perched zones and the regional aquifer (LANL, 2014a). The major effluent discharges include:

- Mortandad Canyon, Pueblo Canyon from its tributary Acid Canyon, and Los Alamos Canyon from its tributary DP Canyon received liquid radioactive effluents during past decades (LANL, 2015c).
- Sandia Canyon has received discharges of power plant cooling water and water from LANL's Sanitary Wastewater Systems Consolidation (SWSC) Plant.
- Water Canyon and its tributary Cañon de Valle have received effluents produced by high explosives processing and experimentation (LANL, 1993a, 1993b).

- Over the years, Los Alamos County has operated several sanitary wastewater treatment plants (WWTPs) in Pueblo Canyon (LANL, 1981). The Los Alamos and White Rock WWTPs are currently operating. LANL has also operated numerous sanitary treatment plants.

- From 1956 through 1976, up to 160,000 pounds of hexavalent chromium were released from cooling towers at a LANL power plant. The chromium was commonly used in industry at the time as a corrosion inhibitor (LANL, 2014b).

Since the early 1990s, LANL has significantly reduced both the number of industrial outfalls and the volume of water discharged. The quality of the remaining discharges has been improved through treatment process improvements so that they meet applicable standards (LANL, 2014a).

Los Alamos groundwater monitoring has defined two areas of notable contamination: RDX contamination beneath Technical Area 16 and chromium contamination beneath Sandia and Mortandad Canyons (LANL, 2015c).

3.3.2 Contaminant Transport Pathways and Velocities

Numerous pathways for potential contaminant transport are present throughout the Pajarito Plateau. Transport modes for contaminants from the surface to the regional aquifer vary according to the hydrogeologic setting and include:

- Matrix flow through nonwelded and poorly welded tuffs (mesa tops and dry canyons)
- Fracture flow through welded tuffs (mountain front and Pajarito Fault zone)
- Fracture and matrix flow through dense and brecciated basalts (Cerros del Rio basalt outcrop at low-head weir and perched intermediate aquifers)
- Infiltration from wet canyons (portions of Los Alamos Canyon, Pueblo Canyon, Mortandad Canyon, Sandia Canyon, and Cañon de Valle)

Transport velocities are highly variable throughout the plateau. Infiltration beneath dry canyons and mesa tops is estimated to be very low, resulting in travel times to the regional aquifer of several hundred to thousands of years (Birdsell et al., 2005). On the other hand, fracture flow through fractured tuffs or basalts is likely to be comparatively rapid in many locations. Although they vary spatially, groundwater velocities are typically on the order of 30 feet per year (LANL, 2016).

Another possible contaminant transport pathway is potential cross contamination between perched aquifers and the regional aquifer during well drilling, primarily when open borehole conditions are maintained over an extended period of time. Well drilling by LANL has incorporated procedures to minimize this risk, such as sealing off zones of saturation above the regional aquifer prior to advancing the borehole to the regional aquifer. Data do not indicate any cases of cross contamination in the monitoring network; however, future drilling should include the procedures that are in place to minimize the risk of cross contamination.

The chemical properties of each contaminant control the degree to which they move into the subsurface. Reactive chemicals have a tendency for adsorption (adhesion of dissolved molecules to the surfaces of solids), limiting their movement in groundwater, while conservative or non-reactive chemicals tend to move readily in groundwater. Examples of these two types of contaminants that have been released from LANL facilities are:

- Non-reactive contaminants include chromium, tritium, nitrate, perchlorate, and RDX (a component of explosives, also known as cyclotrimethylenetrinitramine, cyclonite, hexogen, and T4). These chemicals are highly mobile and are observed in groundwater within perched intermediate zones and the regional aquifer beneath several canyons, including Cañon de Valle, Los Alamos Canyon, Mortandad Canyon, Pueblo Canyon, and Sandia Canyon (LANL, 2005).

- Reactive contaminants include strontium-90, americium-241, cesium-137, plutonium-238, -239, and -240 (LANL, 2005). These contaminants have been detected in the alluvial system but are not observed in the intermediate and regional aquifers.

3.4 Extent of Contamination and Risk to Water Supply

To evaluate the risk of contamination to the LACWU water supply, this section summarizes existing contaminant levels in the regional aquifer (Section 3.4.1) and provides additional detail on percholorate, hexavalent chromium, and other contaminants (Sections 3.4.2 through 3.4.4).

3.4.1 Summary of Contamination in Groundwater

Monitoring of production wells is conducted by the LACWU as part of routine monitoring and compliance with the U.S. Safe Drinking Water Act, and monitoring is also conducted by LANL. Recent monitoring and reporting indicates~~d~~ that all drinking water produced by the LACWU water system meets federal and state drinking water standards. Drinking water wells in the Los Alamos area have not been impacted by LANL discharges with one exception: well Otowi-1 (O-1) in Pueblo Canyon, where perchlorate has been detected below the 2012 LANL Compliance Order on Consent screening level of 4-micrograms per liter (µg/L) (the 2016 LANL Compliance Order on Consent does not include a screening level for perchlorate and the perchlorate standard that will apply going forward is an NMED tap water screening level of 13.8 µg/L). Concentrations of perchlorate in this well are continuing to decline (LANL, 2016). Tritium has also been detected at low levels in well O-1. This well is not being used to supply drinking water due to water leaks in the transmission line, but the LACWU plans to put it back online in the future after this pipeline has been replaced.

Table 3-3 summarizes groundwater contaminants that were detected in the regional aquifer in 2015. These data were downloaded from the LANL and NMED Intellus New Mexico web site (LANL and NMED, 2016). Data for well O-1 has been included on Table 3-3, although there were no standard exceedances for samples collected from this well.

The alluvial and intermediate-perched groundwater bodies are separated from the regional aquifer by hundreds of feet of unsaturated rock and sediments, so recharge from the shallow groundwater occurs slowly. As a result, less contamination reaches the regional aquifer than is found in the shallow perched groundwater (LANL, 2014a). Where contaminants are found at depth, the setting is either a canyon where alluvial groundwater is usually present or a location beneath canyons where large amounts of liquid effluent have been discharged. This section focuses mainly on contamination that has been detected in the regional aquifer, since it is the source of the LACWU water supply.

Discussion of the extent and concentrations of specific contaminants follows.

3.4.2 Perchlorate Contamination

Perchlorate is used as an energetics booster or oxidant in solid propellant for rockets and missiles. An official standard for this chemical has not been established. A screening level for perchlorate of 4 µg/L was set in the LANL Compliance Order on Consent issued by NMED on March 1, 2005 and revised on April 20, 2012 (NMED, 2012); however, a new LANL Compliance Order on Consent was issued in 2016 and it does not include a screening level for perchlorate (NMED, 2016). The perchlorate standard that will apply going forward is an NMED tap water screening level of 13.8 µg/L (NMED, 2014).

Perchlorate contamination is present in groundwater beneath Mortandad Canyon (LANL, 2016). In 2015, perchlorate concentrations exceeded 4 µg/L in samples collected from 8 monitoring wells, one of which (R-15) is completed in the regional aquifer (LANL, 2016). As discussed above, the 2016 LANL Compliance Order on Consent does not include a screening level for perchlorate (NMED, 2016), and the perchlorate standard that will apply going forward is an NMED tap water screening level of 13.8 µg/L (NMED, 2014). The concentrations detected in 2015 in the regional aquifer well R-15 ranged between 7.22 and 9.05 µg/L (LANL and NMED, 2016). The 4-µg/L screening level was the standard in effect in 2015, but with the higher standard being applied in the future, the number of standard exceedances is expected to decrease (any similar concentrations detected in the future will not exceed the 13.8-µg/L screening level). The two monitoring wells with the highest detected concentrations of perchlorate in 2015 were MCOI-5 and MCOI-6 (LANL and NMED, 2016), and these wells are completed in the perched-intermediate aquifer (LANL, 2016). The concentrations detected in these wells in 2015 ranged between 61.1 and 99.4 µg/L (LANL and NMED, 2016).

3.4.3 Hexavalent Chromium

Most contaminants that have been detected in groundwater beneath LANL have concentrations that are largely below regulatory standards; however, a hexavalent chromium plume is present in the regional aquifer. Chromium can be present in either the Cr^{+3} (trivalent chromium) or Cr^{+6} (hexavalent chromium) species. Cr^{+3} is an essential nutrient for humans and occurs naturally in many foods; Cr^{+6} causes various health effects. The U.S. Environmental Protection Agency (U.S. EPA) is currently reviewing data from a 2008 long-term animal study by the Department of Health and Human Service's National Toxicology Program, which concluded that hexavalent chromium may be a human carcinogen if ingested (U.S. EPA, 2015a).

The primary source of chromium is blowdown of potassium dichromate from the TA-03 power plant cooling tower that occurred from 1956 to 1972. LANL's conceptual model hypothesizes that chromium originated from releases into Sandia Canyon and may have migrated along lateral pathways to locations beneath Mortandad Canyon. For this reason, perched-intermediate and regional wells beneath Mortandad Canyon are monitored. Other contamination beneath Sandia and Mortandad Canyons may be associated with Mortandad Canyon sources. These sources and the migration pathways are described in the *Investigation Report for Sandia Canyon* (LANL, 2009) and *Phase II Investigation Report for Sandia Canyon* (LANL, 2012).

As discussed in the original long-range water supply plan (DBS&A, 2006), several exceedances of the New Mexico Water Quality Control Commission (NMWQCC) groundwater standard for human health of 50 µg/L for chromium were observed in samples collected in 2005 from monitoring well R-28. Since the 2006 water plan was completed, the areal extent and concentrations within the plume have been better defined. The chromium plume is located in an area of approximately 1 mile by 0.5 mile and within the top 50 feet of the regional aquifer (LANL, 2016). Data for monitoring wells where there were chromium concentration exceedances of the NMWQCC groundwater quality standard for human health in 2015 are shown on Figure 3-9.

In 2015, **hexavalent** chromium concentrations exceeded the NMWQCC groundwater quality standard in five regional aquifer monitoring wells—R-28, R-42, R-62, R-50 Screen 1, and R-43

Screen 1 (Figure 3-9)—and the highest concentrations of **hexavalent** chromium detected in the plume are near monitoring wells R-42 and R-28. Two intermediate wells (SCI-2 and MCOI-6) also had **hexavalent** chromium concentrations above the standard (LANL, 2016). The monitoring wells located in the center of the plume (R-42 and R-28) show a relatively flat trend in the **hexavalent** chromium concentrations, while monitoring wells along the edge of the plume (R-45 screen 1, R-43 Screen 1, and R-50 Screen 1) show gradually increasing **hexavalent** chromium concentrations (LANL, 2016). The LACWU production well that is located closest to the **hexavalent** chromium plume is PM-3, which is located about ½ mile from R-28 (Figure 3-9). **Hexavalent c**~~C~~hromium detections in monitoring wells R-35a and R-35b (located adjacent to PM-3 and screened deep in the upper louvered section of PM-3 and at the water table, respectively) are at background levels (Katzman, 2016). Well PM-3 could become contaminated in the future, depending on the direction of groundwater flow and on the interim measures being implemented by LANL (discussed below) to control plume migration (LANL, 2015b).

The screened interval in monitoring well R-28 is from 934 to 958 feet deep, extending only 69 feet into the top of the regional aquifer, while PM-3 is screened at much greater depths (from 956 to 2,532 feet), therefore producing water from a much larger section of the aquifer. If the chromium plume were to reach PM-3 yet be confined to a shallow segment near the top of the aquifer, the concentration is likely to be highly diluted as a result of pumping from an interval of more than 1,500 feet. Nevertheless, the presence of **hexavalent** chromium near the well represents a risk that should be carefully monitored. During 2015, the NMED DOE Oversight Bureau coordinated with the NMED Drinking Water Bureau on a scope of work for a potential project to assess the vulnerability of the LACWU water supply wells to contamination; however, due to grant timing and State contracting limitations, the project has been put on hold (Yanicak, 2016). **In the event that any of the production wells are impacted by hexavalent chromium, the LACWU maintains an insurance policy to fund and implement corrective actions, as needed.**

The May 2015 Interim Measures Work Plan (LANL, 2015a) presents LANL's approach for controlling movement of chromium-contaminated groundwater along the downgradient portions of the plume. LANL plans to extract contaminated groundwater, treat it at the surface using ion exchange, and reinject it into the aquifer, with project implementation beginning in 2016 (LANL, 2016). In an October 2015 letter, NMED approved the LANL work plan and set due dates for the interim measure task work plans (NMED, 2015b). Figure 3-10a shows the chromium interim measure project area in relation to the rest of the County, and Figure 3-10b shows the existing and planned extraction, injection, and monitoring wells, and provides an approximate areal extent of the hexavalent chromium-contaminated groundwater that exceeds the 50-µg/L NMWQCC groundwater standard for human health (DOE and LACWU, 2016). The work plan also provides a general description of the planned treatment system, including two ion exchange vessels for treatment and redundancy (LANL, 2015b).

In addition, LANL is conducting work under the July 2015 *Work Plan for Chromium Plume Center Characterization* to further investigate the aquifer in the center of the chromium plume and to further characterize the nature and extent of the contamination in order to identify remedial alternatives for the chromium plume (LANL, 2015b). Objectives include investigating the feasibility of chromium source removal, further characterizing the aquifer—including heterogeneity and dual porosity—in order to evaluate the potential for in situ remedial strategies, studying the hydrologic and geochemical conditions that occur near the proposed injection wells, and characterizing the infiltration beneath the shallow alluvial groundwater in Sandia Canyon (LANL, 2015b). The LANL chromium plume center characterization work plan details planned LANL activities, including extraction well installation, pumping, and sampling, aquifer tracer tests and a field cross-hole trace study, an injection well study, and characterization of infiltration in Sandia Canyon (LANL, 2015b).

LANL plans to work with the LACWU to ensure that the interim measure pumping does not interfere with the water supply pumping and to continue to monitor water quality in the monitoring and water supply wells (LANL, 2014c). In addition, LANL will prepare a corrective measures evaluation report that proposes the final remedy for the chromium plume (LANL, 2015b).

3.4.4 Other Contaminants in Groundwater

A number of additional contaminants have been detected in groundwater, including nitrate, RDX, tritium, trichloroethene, and radioactive contaminants. These contaminants are discussed briefly in the sections that follow.

3.4.4.1 Nitrate

Nitrate (NO_3 as nitrogen) has been detected in the regional aquifer at concentrations of up to 6.1 mg/L in monitoring wells R-43 S1 and R-11 in Sandia Canyon and R-42 in Mortandad Canyon (the U.S. EPA national primary drinking water standard and NMWQCC groundwater standard for human health are both 10 mg/L). Nitrate (as N) concentrations are also elevated (> 2 mg/L) in samples from regional aquifer monitoring wells R-36 in Sandia Canyon and R-15, R-28, and R-45 in Mortandad Canyon (LANL, 2014a).

3.4.4.2 RDX

RDX, a component of explosives, has been detected in groundwater. An official standard for this chemical has not been established; however, the EPA's tap water screening level for RDX is 0.70 µg/L (U.S. EPA, 2016). LANL indicated that EPA is using a target risk of E–6 for RDX (0.70×10^{-6} µg/L), and that NMED requires LANL to use a target risk of E–5 (Katzman, 2015). The RDX standard used by LANL is 7.0 µg/L (NMED, 2015a).

RDX is monitored by LANL, and RDX concentrations exceed LANL's 7.0-µg/L standard at two springs (Burning Ground Spring and Martin Spring), one alluvial well (CdV-16-02659), and three intermediate-perched zone wells (CdV-16-4ip S1, CdV-16-2(i)r, and CdV-16-1(i)) near TA-16 in the Water Canyon watershed (LANL, 2015c). RDX is also persistently detected in regional aquifer monitoring wells R-18 and R-63 at concentrations that are below the standard. In 2015, the maximum concentrations detected were 1.66 µg/L in R-63 and 2.86 µg/L in R-18. The concentrations in R-63 have been relatively steady since this well was installed in 2011, with the exception of the first few samples following well construction. Detected concentrations in R-18 show an increasing trend since the well was completed in 2006 (LANL, 2016).

3.4.4.3 Trichloroethene and Tetracloroethene

Chlorinated solvents are present in the groundwater near TA-16 (LANL, 2015c). Trichloroethene (TCE) was detected in Pajarito Canyon regional aquifer monitoring well R-20 S2 beginning in late 2008 and continued to be detected in every sampling event through 2011. In 2015, TCE was not detected in R-20 S2 (LANL and NMED, 2016). In 2014, tetrachloroethene (PCE) and TCE were detected in alluvial well FLC-16-25280 at concentrations above the U.S. EPA national primary drinking water standards of 5 µg/L (LANL and NMED, 2016).

3.4.4.4 Radioactive Contaminants

Radioactive effluent was discharged into Los Alamos Canyon during the earliest Manhattan Project operations at TA-01 (1942 through 1945) and from nuclear reactors at TA-02 (until 1993). Liquid and solid radioactive wastes were also discharged in Los Alamos Canyon from TA-21, and radionuclides and metals were discharged from the sanitary sewage lagoons and cooling towers at the Los Alamos Neutron Science Center at TA-53. Compared with past decades, little radioactivity is now found in groundwater samples. In 2013, strontium-90 was detected in shallow alluvial wells in DP and Los Alamos Canyons, at concentrations of up to 17 picocuries per liter (pCi/L) (LANL, 2014a). The U.S. EPA has established a national primary drinking water standard of 4 millirem per year (mrem/yr) for beta particle and photon radioactivity from man-made radionuclides in drinking water (including strontium-90, which emits beta particles during radioactive decay). Based on conversions provided by the U.S. Department of Commerce Bureau of Standards, the derived concentration of 8 pCi/L is equivalent to a dose of 4 mrem/yr for strontium-90 (U.S. Department of Commerce, 1959; U.S. EPA, 2015b). Samples collected from alluvial well LAO-3a continue to exceed the standard. In 2015, the strontium-90 concentration in this well was 12.4 pCi/L (LANL and NMED, 2016).

Tritium activities in groundwater peaked in the early 1980s and have since declined. Tritium was detected in water supply well O-1 at an activity of 2.373 pCi/L in 2015 (LANL and NMED, 2016). In the intermediate zone monitor wells MCOI-5 and MCOI-6, tritium was detected in 2015 at activities of 3,140 and 2,940 pCi/L, respectively. The U.S. EPA's dose-based drinking water standard for tritium is 4 mrem/yr, based on a maximum contaminant level of 20,000 pCi/L (U.S. EPA, 2002).

3.5 Surface Water Supply

Though most of the LACWU water supply is from groundwater, there are two sources of surface water supply:

- The Los Alamos Canyon reservoir has provided non-potable water supplies to schools, parks, and a golf course. The reservoir filled with debris following the 2000 Cerro Grande Fire, and the area was further impacted by the 2011 Los Conchas fire and subsequent flooding. The debris was cleared and reservoir repair and reconstruction was completed in the spring of 2013, but a flood in September 2013 filled the reservoir with silt again. The reservoir has been dredged and the LACWU plans to install a new pipeline from the reservoir into town in order to connect to the existing non-potable infrastructure (Meyers, 2016).

- LACWU has the potential to use Rio Grande surface water from the San Juan-Chama Project in the future, though a diversion structure has not yet been constructed. Bringing the San Juan-Chama Project water online would diversify the water supply **geographically and also in terms of water rights**, helping the LACWU to mitigate any future effects due to contamination of existing wells and/or climate change. Details of the proposed San Juan-Chama Project and LACWU water rights are discussed in Section 4.

Since surface water supplies only non-potable supplies to LACWU, surface water contamination is not a primary issue for drinking water quality. However, careful management of stormwater runoff, particularly in areas impacted by fire, is an important water resource management issue for Los Alamos County, as discussed in Section 7. Surface water quality will become more of an issue **if and when a project to use** ~~once the~~ San Juan-Chama Project **water** comes online.

4. Water Rights

In addition to having sufficient physical supply, the LACWU needs to have the legal rights to use the water. New Mexico water law is founded on the principle that all water in New Mexico belongs to the State of New Mexico, which thus has the sole authority to grant or recognize rights to use that water. Two further tenets, both based on New Mexico Constitution Article XVI, Section 2, are that (1) water rights "are subject to appropriation for beneficial use, in accordance with the laws of the state" and (2) "priority of appropriation shall give the better right."

- The concept underlying the principle of prior appropriation is that the first person to use water for a beneficial purpose has a prior right to use that water against subsequent appropriators. Water rights acquired through this system of prior appropriation are a type of property right and may be sold or leased.

- The essential basis of water right ownership is beneficial use. The principle of beneficial use is that a water right arises out of a use that is productive or beneficial, such as agricultural, municipal, industrial, and domestic uses, among others.

The State Engineer, through the OSE, administers water rights for the State of New Mexico:

- To actively manage groundwater resources in New Mexico, the State Engineer has the authority, as set forth in the Water Code, to delineate groundwater basins that require a permit for groundwater withdrawals. Such a permit specifies (1) how much water a user can withdraw in any given year, (2) the location and type of well that will be used to withdraw the water, and (3) the use to which the water will be put. Many water right permits have special conditions that further define the use and quantity of water allowed under the permit.

- Like groundwater, the diversion of water from New Mexico's surface waters requires either a declaration, permit, license, or court decree to divert the water. Surface water appropriations follow the same standards as groundwater rights in that a transfer or lease cannot impair existing water rights and must not be contrary to public welfare or conservation (NMSA 72-5-23, 72-12-3(D)).

Many of New Mexico's surface waters are governed by interstate compacts that require set amounts of water to be delivered to specified delivery points. The Interstate Stream Commission, an adjunct commission to the OSE, has responsibility for ensuring that specific rivers in New Mexico meet their obligations under their respective interstate compacts.

4.1 Water Rights

The LACWU has existing water rights from a variety of sources, including water rights from the Rio Grande surface water and underground water basins and rights to use 1,200 acre-feet of water from the San Juan-Chama Project. The U.S. DOE also owns Rio Grande underground water basin rights. These rights are discussed in Sections 4.1.1 and 4.1.2, respectively.

4.1.1 Rio Grande Surface Water and Groundwater Rights

As discussed in Section 2, the LACWU's Rio Grande water rights were originally owned by the U.S. DOE. In 2001, 70 percent ownership was transferred to the LACWU, and DOE retained 30 percent ownership. Table 4-1 summarizes these permitted, licensed, and declared water rights.

The rights outlined in Table 4-1 are based on a permit application filed by U.S. Energy Research on May 29, 1975 to combine a series of previously licensed and declared water rights. That application requested a total right of 5,547.1 ac-ft/yr for municipal, industrial, and related purposes that could be diverted from any combination of permitted points of diversion. The OSE approved the application on October 30, 1975 with the exception of subtracting 5.8 ac-ft/yr for evaporation losses at Los Alamos Reservoir. Figure 4-1 shows the LACWU water diversions for 2010 to 2015 (these volumes were calculated by subtracting LANL demands from total diversions), and Figure 4-2 shows the LANL water use volumes for the same period, in comparison to their respective groundwater rights. Figure 4-3 shows the LACWU water diversions and LANL water use volume, along with the water rights for both entities. The

LACWU has an extension of time for putting their rights to beneficial use that will expire on September 30, 2017.

Table 4-1. Summary of Water Rights

Permit Number	Water Source	Priority Date	Quantity of Water Originally Appropriated (ac-ft/yr)
RG-485 through RG-496-Comb-S-4 [a]	Groundwater	1948-1951	5,329
RG-485 through RG-496-Comb-S-5 [b]	Groundwater	1948-1951	50
1503,1802, and 1802-amended [c]	Surface water	March 14, 1922	168.1
Evaporation loss	Surface water	NA	(5.8)
		Total water rights	5,541.3 [d]

Source: Southwest Water Consultants, Inc., 1999

[a] Permitted August 31, 1965 from numerous underground water right declarations filed on March 5, 1957 and amended in 1965. These declarations identified actual use of 3,966 acre-feet in 1964, a capacity of 6,579 ac-ft/yr, and an OSE feasible diversion of 5,329 ac-ft/yr. Dates that water was put to beneficial use vary.

[b] Subsequent declarations added an additional 50 acre-feet and new points of diversion.

[c] The amendment to Permit 1802 raised the storage capacity from 6.66 acre-feet to 28.33 acre-feet.

[d] Of the total 5,541.3 ac-ft/yr under the 1975 combined permit, the LACWU owns 70 percent (3,878.91 ac-ft/yr) and DOE owns 30 percent (1,662.39 ac-ft/yr).

The LACWU (which is the sole water provider for LANL) leased the DOE-owned water rights from 2001 to 2011, when the lease expired. In May 2016, an application for permit to change an existing water right was filed jointly by DOE and the LACWU in support of the chromium plume control interim measure and chromium plume center characterization project (U.S. DOE and LACWU, 2016). In addition, a Request for Emergency Authorization associated with the joint application was submitted, and emergency authorization was received on September 10, 2016 (NMOSE, 2016). The application and emergency authorization request were filed jointly because of the nature of the existing permitted rights between the DOE and the LACWU (U.S. DOE and LACWU, 2016).

The application requests a change in purpose of use for groundwater to add groundwater remediation and additional groundwater points of diversion (PODs) to be used for control and future characterization of hexavalent chromium-contaminated groundwater at LANL (U.S. DOE and LACWU, 2016). The application calls for 24 additional PODs (3 extraction wells, 6 injection wells, and 15 monitoring wells). The volume of water for this application is 679 ac-ft/yr (U.S. DOE and LACWU, 2016), and LANL also plans to file for return credits from the OSE.

Operation of the additional PODs will not impair or increase the appropriation of water above the existing permitted water rights between DOE and the LACWU (5,541.3 ac-ft/yr total) (U.S. DOE and LACWU, 2016). On September 10, 2016, the OSE approved the request for Emergency Authorization and issued Emergency Authorization, RG-00485 et al. (NMOSE, 2016).

~~Using 679 ac-ft/yr of the DOE-owned water rights for the LANL chromium project leaves 983.39 ac-ft/yr of DOE-owned water rights.~~ The LACWU **continues to negotiate** ~~plans to enter into~~ a new lease with DOE for the ~~remaining 983.39~~ **full 1,662.39** ac-ft/yr, for use by all customers, including LANL **and the chromium interim measure** (Meyers, 2016).

In 2006, the OSE approved a 30-ac-ft/yr surface water diversion from Los Alamos Canyon for snowmaking**, which is included in the existing total water rights volume of 5,541.3 ac-ft/yr**. The purpose of use was changed from municipal and industrial to municipal, industrial, recreational, and snowmaking. ~~The proof of completion of works was accepted by the OSE in August 2010. The diversion could be increased up to 120 ac-ft/yr with the filing of a return flow plan, provided that the consumptive use did not exceed 30 ac-ft/yr. These water rights are referred to as the Camp May water rights (SP-1802-C). In 2009, the OSE approved an additional POD to fill a storage tank or reservoir for snowmaking at the Pajarito Ski Area. The coordinates for the new POD will be x = 1,646,410.77 and y = 1,771,027.64 (New Mexico State Plane NAD83 coordinates), within Township 19 North, Range 5 East, Section 10. In November 2014, the OSE approved an extension of time for submitting proof of completion of works, and proof of application of water to beneficial use is due to the OSE by September 30, 2017.~~

4.1.2 San Juan-Chama Surface Water Rights

Implementation of a project to use San Juan-Chama Project water will help to diversify the Los Alamos County water supply, both geographically and from a water rights perspective. The San Juan-Chama Project surface water originates in the Colorado River Basin and provides a source of supply that is geographically separate from the regional aquifer near Los Alamos. This geographic separation will be a benefit~~,~~ should there be expanded water quality contamination issues in the local groundwater in the future. Additionally, as a federal project, San Juan-Chama Project water contracts are not subject to OSE priority issues, although they may be subject to water rights

DRAFT

administration (discussed in Section 4.3.1 and 4.3.2). The San Juan-Chama Project water rights may also be subject to shortage sharing on a pro rata basis among all contractors in drought years, as discussed in Section 4.3.3. Even with some drought vulnerability, having a separate source of supply could help to provide back-up supply~~,~~ if contamination or water rights issues affect the use of the regional aquifer.

Los Alamos County has contracted water rights with the U.S. Department of the Interior Bureau of Reclamation for 1,200 acre-feet of San Juan-Chama Project surface water, which flows into the Rio Grande through a series of tunnels, conveyance channels, and reservoirs. ~~Los Alamos County has a service contract for 1,200 acre-feet of San Juan-Chama Project surface water, which flows into the Rio Grande through a series of tunnels, conveyance channels, and reservoirs. The current contract has an expiration date of 2017. Los Alamos County's San Juan-Chama service contract was converted to a repayment contract, which eliminates expiration dates and the need to renegotiate and renew the contract. Under the amended repayment form of contract, the annual payments are viewed as repayment of Los Alamos's allocated construction cost obligation instead of annual water service charges, as was the case under the former water service form of contract (USBR, 2007).~~**Los Alamos County's San Juan-Chama contract was converted from a service contract to a repayment contract in October 2006, and the LACWU completed repayment of the contract (Los Alamos County's share of the San Juan-Chama Water Project construction costs) in December 2015. Under the current contract, remaining payments are for operation, maintenance, and replacement costs only (SJ-C Project Contract No. 05-WC-40-560).**

A final preliminary engineering report (PER) was completed for the LACWU San Juan-Chama **Project** water supply project in September 2012. The PER evaluated five alternatives for diverting, treating, and conveying the San Juan-Chama Project water and **recommended**~~selected~~ the alternative that called for the installation of three wells in White Rock (CDM Smith, 2012). Under this alternative, groundwater that would have naturally discharged to the river would be pumped, and the San Juan-Chama **Project** water would replace the pumped groundwater in the river (CDM Smith, 2012). This alternative would not require treatment above disinfection, and the proposed well locations would allow for connection to the water system at an existing booster station (CDM Smith, 2012). ~~Public concerns have~~

DRAFT

~~been raised over the proposed well locations, and t~~The Los Alamos County Council advised that **further study of alternatives and** an environmental assessment be completed before the project moves forward (LACWU, 2014).

The environmental assessment will provide an opportunity to re-evaluate specifics of the project design in light of environmental and public concerns. In July 2014, the Utilities Manager recommended delaying further action on the San Juan-Chama Project diversions until the 40-year water plan update has been completed (LACWU, 2014). **Through the environmental assessment and further planning processes, LACWU will need to consider the benefits of the separate San Juan-Chama Project water supply in relation to costs and other concerns, and to determine when and if to construct a project that would bring this water online.** ~~Bringing the San Juan-Chama Project water online would diversify the water supply, helping the LACWU to mitigate any future effects due to contamination of existing wells and/or climate change.~~

4.2 Water Rights Administration

As part of the planning process, it is important to view the LACWU's water rights in the larger context of the administrative and other legal considerations that could affect the LACWU's ability to use and divert its water rights in any given year. This section discusses the administrative policies currently or potentially affecting the LACWU's water rights; Section 4.3 assesses the potential risks to those water rights.

4.2.1 Rio Grande Compact

Water in the Rio Grande is governed by the Rio Grande Compact, an agreement entered into by New Mexico, Texas, and Colorado in 1939 and approved by the United States Congress and the State of New Mexico (NMSA 72-15-23). The Compact applies to the use of surface water of the Rio Grande, from its headwaters in Colorado to Fort Quitman, Texas, by each of the three states. Each upstream state is required to make a surface water delivery to its downstream neighbor. The volumes of water required to be delivered to New Mexico and Texas are calculated based on upstream flows, and an annual accounting is conducted to determine each

DRAFT

state's actual deliveries in relation to that delivery obligation and the resulting credits or debits (over- or under-deliveries), which are carried over from year to year.

New Mexico's Compact delivery requirements are based on an inflow-outflow schedule where inflow is measured at the Rio Grande at Otowi Bridge near San Ildefonso, NM gage (Otowi gage) east of Los Alamos. Because of the Otowi gage's role in determining delivery amounts, the State Engineer has a long-standing administrative practice of not permitting a change in point of diversion from one side of the gage to the other, whether by sale or by lease (Cartron et al., 2002). This requirement places a significant restriction on the water rights market, and coupled with the fact that few pre-1907 water rights are available for purchase, means that purchasing water rights, whether for municipal use or offsets (Section 4.2.4), will be a significant challenge. Additionally, even if a willing seller can be identified, water rights transfers on the Rio Grande are routinely protested and can require expenditure of significant technical and legal fees.

4.2.2 Protection of Senior Water Rights

As discussed above, the State of New Mexico adheres to the prior appropriation system for water rights administration. This approach is based on a "first in time, first in right" concept, whereby the water right holder with a priority date senior to other rights can exercise that right to the detriment of a right with a junior priority date. When senior water right holders are unable to fully exercise their right due to diversions by junior water right holders, they can make a priority call on a river (including stream-connected groundwater rights). This call, which would be administered by the OSE, would require junior users to cease pumping or diverting so that the senior rights could be fulfilled.

To date, priority call-based administration has rarely happened; however, most rivers and connected groundwater basins are over-appropriated. Even though the Rio Grande Basin has not been adjudicated (a legal process that establishes the amounts and priority dates of all surface water and groundwater rights in a stream system), LACWU water rights are junior to a significant number of downstream senior water rights, such as the Middle Rio Grande Conservancy District, that could be impacted by additional depletions upstream. With additional growth and other pressures, such as endangered species requirements, active administrative protection of senior water rights in groundwater basins and rivers is likely to become more frequent over the 40-year planning horizon.

4.2.3 Active Water Resource Management

In an effort to develop more flexible tools for administering water rights in New Mexico, the OSE adopted Active Water Resource Management (AWRM) regulations (NMAC 19.25.13.1 to 13.49) in December 2004. The AWRM legislation creates an administrative framework within which the OSE will establish water master districts, appoint water masters for those districts, and develop district-specific water rights administration regulations.

The OSE has established seven priority basins for AWRM (NMOSE, 2004a), including the Lower Rio Grande. Over time, the OSE may extend the AWRM program to the Upper Rio Grande and develop regulations that will address administration of water rights, although the regulations will not become final until the Rio Grande Basin has been adjudicated (NMOSE, 2004b). In the Pecos River and connected groundwater basins, the OSE has developed AWRM regulations that clearly lay out several approaches to priority administration, all of which allow for curtailment of junior water rights to protect senior water rights.

4.2.4 Rio Grande Offset Requirements

In accordance with statutory authority and case law, the OSE manages the Rio Grande surface water and groundwater basins conjunctively and considers Rio Grande surface water to have been fully appropriated as of the year 1939 (the year the Rio Grande Compact was signed) (NMOSE, 2000). This means that the OSE recognizes the groundwater-surface water connection and conditions permits so that new groundwater appropriations will not increase surface water depletions and thereby affect senior water right holders. Specifically, the OSE requires applicants for groundwater rights to purchase and retire valid water rights in an amount equivalent to the effect the groundwater withdrawals will have on the river.

Previously, the OSE didn't require applicants to immediately begin purchasing and retiring water rights. However, current policy, which was upheld in a case involving the City of Rio Rancho, specifies that offsets must be in place to counteract the effect of pumping on the river. A phased acquisition of the offsets is possible, especially if the applicant is not planning to immediately pump up to the full permitted amount; however, offsets for impacts must be in place by the time those impacts affect the river (i.e., increase depletion).

The OSE has further clarified this policy, stating that offset rights may be valid only for pre-1907 rights, a pre-1907 surface water right previously transferred into a well, or an existing groundwater right with a priority date older than May 31, 1939, the date of the Rio Grande Compact (NMOSE, 2006). This policy limits the number of water rights that could be considered for offset requirements.

4.2.5 Rio Grande Declared Underground Water Basin

The Rio Grande Underground Water Basin covers 26,209 square miles along the Rio Grande in the center of the state. Although specific administrative criteria exist for the area near the river in the Middle Rio Grande (the reach from Cochiti to Socorro) (NMOSE, 2000), the OSE has no unique administrative criteria for the portion of the Rio Grande Basin near Los Alamos County. The OSE evaluates applications for water rights in this reach, including a change in point of diversion or place and purpose of use of water rights, to determine whether the granting of the application will impair existing water rights or be detrimental to the public welfare or contrary to the conservation of water.

4.3 Risks to Los Alamos County Water Rights

Although the LACWU owns a specific volume of water rights, the legal right to divert and use those rights in any given year can be affected by the rights of other water rights holders and even as a result of interstate compacts or other agreements governing interstate waters. These risks are discussed in the following subsections.

4.3.1 Protection of Senior Water Rights

As discussed in Section 4.2.2, the LACWU could potentially be subject to limitation of its water rights in order to protect senior water rights. A significant yet unquantified number of the water rights on the Rio Grande are senior to those of the LACWU. In the event that the OSE begins administering priorities based on a call or based on AWRM regulations, the LACWU could be required to limit its use or to use some of its San Juan-Chama Project water to mitigate the effects of its diversions on senior water right holders. Until the OSE conducts a hydrographic survey and adjudicates the Rio Grande Basin, however, it is impossible to quantitatively evaluate the LACWU's susceptibility to curtailment of its water rights under priority administration.

4.3.2 Rio Grande Offset Requirements

Even without a priority call, the OSE could potentially require the LACWU to offset its current pumping to avoid impairment of pre-1939 senior water rights holders. For example, should the LACWU submit an application to change the POD or purpose and place of use of a water right, the OSE would evaluate that application with respect to impairment, public welfare, and conservation. Because the LACWU's use of its water rights increases depletions on the Rio Grande, thereby impacting senior water rights holders, the OSE could require offsets due to impairment even though the existing permits have no offset requirement. As discussed in Sections 4.2.4 and 6, the LACWU could satisfy those offset requirements by using San Juan-Chama Project water as offset rights or by purchasing water rights. However, willing sellers of pre-1907 water rights are difficult to find, and many municipalities have encountered difficulties in identifying water rights to purchase.

The LACWU might also be able to reduce the number of offset water rights the OSE would require by applying to the OSE for return flow credit for the treated wastewater effluent it returns to the Rio Grande. Credit for return flow to the aquifer is also possible. Both types must be demonstrated in a return flow plan subject to OSE approval (NMOSE, 2000, Section 3).

4.3.3 Navajo Water Rights Settlement Provisions

The original legislation authorizing the San Juan-Chama Project includes provisions for sharing shortages among beneficiaries of the project (76 Stat. 96, PL 87-483). The Northwestern New Mexico Rural Water Projects Act (123 Stat. 1372, PL 111-11) was enacted on March 30, 2009, and Section 10402 amends Public Law 87-483, providing additional detail about shortage sharing. The Navajo Water Rights Settlement, which was approved in August 2013, defines flows and other requirements in a manner that could result in shortages to the San Juan-Chama Project. These shortages would likely be shared on a pro rata basis among all contractors. Although conditions giving rise to shortage sharing may be rare, implementation of the act could nonetheless reduce the quantity of San Juan-Chama **Project** water available to contractors in some years. **Predicted changes in San Juan-Chama Project water allocations resulting from climate change are discussed in Section 7.**

4.4 Acquisition of New Water Rights to Meet Future Demand

As discussed in Section 6, the LACWU could be required to obtain additional water rights to meet future water demand, or to move points of diversion for existing rights if contamination affects supply wells (Section 3). As the Rio Grande basin is considered to be fully appropriated, the LACWU would have to purchase water rights to meet future needs, which may not be feasible given water market limitations. The LACWU should consider maximizing use of its existing water rights through conservation or reuse and through maximizing return flow credits.

4.5 Los Alamos National Laboratory

In September 2009, LACWU signed an agreement with DOE to provide water service to LANL for the period October 1, 2009 through September 30, 2019, and the County will be the sole water provider for LANL at least through the term of this agreement. The contract indicates that DOE will provide support to LACWU for implementing use of San Juan-Chama Project water. The contract also identifies other terms of service such as meter testing, access to wells for hydrologic monitoring, water storage for firefighting, and water rates. Estimated quantities of water to be provided to LANL range from 412,000,000 gallons (1,264 acre-feet) in 2010 to

DRAFT

572,000,000 gallons (1,743 acre-feet) in 2019. The contract recognized that predicting future water needs for LANL is difficult and included provisions for notification if the future water needs were expected to increase by more than 50,000,000 gallons (153 acre-feet) per year. The agreement also includes a curtailment plan with provisions to reduce water use during times of shortage. LANL provided a 10-year water demand forecast (fiscal year 2017 through fiscal year 2027) in support of this plan update, with values ranging between 254,610,000 gallons (781 acre-feet) and 490,510,000 gallons (1,505 acre-feet) (Ballesteros Rodriguez, 2016) (Section 5).

5. Water Demand

In order to assess the LACWU's projected future demand for water, this section discusses current and historical water uses (Sections 5.1 and 5.2) and demographic and economic trends (Section 5.3). Based on this information, projected future water demands for the region are presented in Section 5.4.

5.1 Historical Use

Groundwater and surface water have supplied the community of Los Alamos for 60 years. Figure 5-1 and Table 5-1 show the metered diversion amounts from wells and surface water from 1947 through 2015. Table 5-2 shows water diversions and population by decade from 1950 through 2010.

Between 1950 and 2000, population increased in Los Alamos County, and since 2000, the population has decreased by approximately 2 percent (Table 5-2). Diversions also increased between 1950 and 1990, due to increased population, and decreased between 1990 and 2010, partially due to water conservation efforts.

Diversions fluctuate significantly from year to year due in part to fluctuating levels of precipitation (Figure 5-2). For instance, in 2012 precipitation was 8.76 inches, and total system demand was 156 gallons per capita per day (gpcd). In 2014, precipitation was 16.82 inches, and total system demand was 135 gpcd.

Demand from the LANL's operations also impacts the magnitude of diversions. Figure 5-3 shows the monthly variation in water use in 2014, with an annual diversion for LANL of 29 percent and 71 percent for the LACWU. While demand in summer months triples for the LACWU due to outdoor watering, the monthly range in water use by LANL varies less. In 2014, LANL used the greatest volume of water in November.

The LACWU has been using the GPCD (gallons per capita per day) calculator developed by the OSE to calculate per capita use since 2007. This allows the County to evaluate water use apart from the bulk water sales to LANL. The per capita values calculated for the total water system demand and by sector for 2007 through 2014 are presented on Table 5-3. Since 2007, total system water demand has ranged between 133 and 157 gallons per day. For the single-family residential sector, per capita demand has ranged between 91 and 120 gallons per day.

Table 5-3. Los Alamos County Per Capita Demand

Year	Sector			Annual System Total
	Single-Family Residential	Multi-Family Residential	Industrial, Commercial, and Institutional	
2007	100	55	32	153
2008	105	55	29	157
2009	91	51	26	137
2010	105	53	29	133
2011	117	59	31	149
2012	120	60	31	156
2013	102	56	22	137
2014	104	54	23	135

Sources: Los Alamos County (2007-2013 data)
LACWU, 2015 (2014 data)

5.2 Current Water Use

The total population served by the LACWU includes the 17,950 residents estimated to live within Los Alamos County in 2010, primarily in the communities of White Rock and Los Alamos.

Table 5-4 shows the monthly and annual billing data by sector for 2010 through 2015. The total system water demand by LACWU (excluding LANL sales) was 135 gallons per day in 2014. In 2014, the per capita demand for the single-family residential sector was 104 gallons per day (Table 5-3). As shown in Figure 5-3, water use increases in the summer months for landscape watering.

In 2014, single-family residential water use accounted for 44.7 percent of LACWU water use (excluding LANL), and multi-family residential water use accounted for 11.6 percent of LACWU

DRAFT

water use. Industrial, commercial, and institutional water use accounted for 14.8 percent of the LACWU's water use, with LANL sales accounting for 28.8 percent of the billed totals (Figure 5-4a). In 2015, single-family residential water use accounted for 43.4 percent of LACWU water use (excluding LANL), and multi-family residential water use accounted for 11.5 percent of LACWU water use. Industrial, commercial, and institutional water use accounted for 16.2 percent of the LACWU's water use, with LANL sales accounting for 28.9 percent of the billed totals (Figure 5-4b).

Comparing the billed totals (Table 5-4) to total diversions (Table 5-1), there was a total of 156 million gallons of non-revenue water in 2014 and 185 million gallons of non-revenue water in 2015. Non-revenue water can include unmetered deliveries~~ (when a meter is broken)~~, leaking pipes in the delivery system, and periodic flushing of the system. The LACWU has performed a water audit following the International Water Association/American Water Works Association (IWA/AWWA) water audit methodology using data for fiscal year 2014 (Table 5-5). This analysis found a total of 86.4 million gallons in non-revenue water (LACWU, 2015). (The large discrepancy between the two results may be due to the different time periods, that is, calendar versus fiscal years).

Indoor watering is estimated as the average water demand for December, January, and February. Comparing the average summer (June, July, and August) and winter demands for the single-family residential sector in 2014, approximately 66 percent of the average summer demand was used outdoors, with the remaining 34 percent used indoors. Comparing the average summer and winter demands for the multi-family residential sector in 2014, approximately 42 percent of the average summer demand was used outdoors and 58 percent was used indoors. Comparing the average summer and winter demands for the single-family residential sector in 2015, approximately 59 percent of the average summer demand was used outdoors, with the remaining 41 percent used indoors. For the multi-family residential sector in 2015, approximately 28 percent of the average summer demand was used outdoors and 72 percent was used indoors.

For more than 70 years, Los Alamos County has used treated wastewater to irrigate turf for a golf course and parks during summer months. The golf course built in Los Alamos in the 1940s has never been irrigated with anything but effluent. As discussed in Section 2, the LACWU has a non-potable water system that uses treated wastewater effluent for irrigation of several areas in Los Alamos and White Rock, for fire protection, and for snow making at the Pajarito Mountain Ski Area. Table 5-6 shows the monthly volume of treated effluent that was reused in 2010 through 2015; almost 72 million gallons was reused in 2015.

Table 5-6. Water Reuse, 2010-2015

Month	Reuse (gallons)					
	2010	2011	2012	2013	2014	2015
January	81,600	104,800	0	0	0	0
February	107,100	96,900	0	0	1,012,477	0
March	145,200	7,369,900	5,638,165	3,867,063	4,544,270	2,311,815
April	11,178,612	14,612,700	9,032,844	11,552,192	7,256,932	10,895,334
May	11,427,200	19,023,600	17,904,886	20,165,106	14,125,782	5,531,325
June	23,262,400	22,388,800	24,743,657	21,739,135	18,148,354	14,975,357
July	12,140,000	21,091,000	16,050,773	9,850,279	8,197,735	2,916,420
August	5,531,600	7,950,983	18,097,000	10,504,260	12,815,537	12,186,453
September	18,847,100	4,660,344	13,174,880	7,470,298	16,036,338	16,723,354
October	8,367,300	6,392,581	11,028,777	6,106,035	7,517,914	6,133,506
November	249,300	1,293,627	4,256,322	876,738	1,651,125	321,250
December	126,800	0	0	0	0	77
Total	91,464,212	104,985,235	119,927,304	92,131,106	91,306,464	71,994,891
Total (acre-feet)	281	322	368	283	280	221

5.3 Population Projections

The Bureau of Business and Economic Research (BBER) at the University of New Mexico has prepared multiple population projections for Los Alamos County, by examining the growth rate in the previous decades, the age of the population, current rates of in-migration, and death and birth rates (BBER, 1996, 2000). Because Los Alamos County's growth rate slowed significantly in the 1980s and 1990s, the 1996 and 2000 projections for growth were very small, showing an increase of only about 3,000 people (Table 5-7). The previous long-range water supply plan (DBS&A, 2006) presented the BBER projections, but did not use them to project demand,

DRAFT

because they did not take recent land transfers and plans for growth into account. Instead, the 2006 projections were based on the growth scenario identified in the August 2004 New Mexico First Town Hall (Fruth, 2004), which showed that a full build-out could occur rapidly, increasing the population to 25,000 people in 2020 (Table 5-7). Contrary to these projections, the population in Los Alamos County actually declined between 2000 and 2010 (Table 5-2), largely due to a reduction in the work force at LANL.

Table 5-7. Population Projections for Los Alamos County 2000 through 2060

Year	Population Census	BBER (1996)	BBER (2000) [a]	Fruth (2004)	BBER (2012)	2014 Population Projections [b]	
						Low	High
2000	18,343	19,317	19,234	18,359	—	—	—
2004	18,796	19,647	19,505	18,796	—	—	—
2005	18,407	19,729	19,573	19,189	—	—	—
2010	17,950	20,123	19,913	21,155	—	—	—
2015	NA	20,601	20,318	23,120	—	—	—
2020	NA	21,079	20,722	25,086	18,063	17,988	20,000
2030	NA	21,758	21,289	—	17,880	17,789	20,812
2040	NA	22,141	21,627	—	17,210	17,123	21,447
2050	NA	22,291	21,761	—	—	16,480	21,874
2060	NA	22,404	21,854	—	—	15,863	22,092

[a] Based on BBER's (2000) "most likely" scenario
[b] Poster Enterprises, 2014

— = Population not estimated for this decade
NA = Not yet available

The State of New Mexico prepared updates of the 16 regional water plans that were published in 2016, and population projections were prepared by a market research consultant as a part of this effort (Poster Enterprises, 2014). BBER released new population projections in November 2012 that project population by decade through 2040, and these projections were extended by the ISC market research consultant in 10-year increments through 2060 using the BBER growth rate trends as a basis for the extensions. Interviews were conducted to obtain input on growth trends and potential water conservation measures, with the feedback being used to refine the projections. Two population projections were developed for Los Alamos County, with the high forecast assuming that the County's goal of a population of 20,000 is achieved in 2020, with a very low rate of growth thereafter, and the low forecast closely tracking the BBER projections (Table 5-7).

The high and low population projections that have been developed for Los Alamos County as part of the regional water planning effort have been used as the basis for projecting demand as part of the updated long-range water supply plan. In addition, a separate water demand forecast was obtained from LANL (Table 5-8). There is considerable uncertainty in developing forecasts for LANL over a 40-year horizon, because its mission and size is dependent on political and national security decisions that could result in a wide range of possible activity.

Table 5-8. Los Alamos National Laboratory 10-Year Water Forecast

Fiscal Year	Estimated Annual Consumption (gallons)	Water Demand [a] (acre-feet)
2017	254,610,000	781
2018	262,160,000	805
2019	268,950,000	825
2020	299,110,000	918
2021	363,180,000	1,115
2022	380,760,000	1,169
2023	387,690,000	1,190
2024	389,650,000	1,196
2025	411,700,000	1,263
2026	482,980,000	1,482
2027	490,510,000	1,505

Source: Ballesteros Rodriguez, 2016
[a] The LACWU provides the LANL water supply, so these demands have been included on Table 5-9.

A conceptual master plan has been developed for a new development that is planned in White Rock (Baer, 2016). The A-19 tract development will have a maximum residential density of 8.7 dwelling units per acre, and a total of 160 dwelling units are proposed (Baer, 2016). This will be a private development, although the potential buyer is still in due diligence and the property still belongs to the County (Baer, 2016). The proposed A-19 tract development was not called out specifically in the ISC population projections; however, the high population projection will account for this growth. The 2010 Census reported a County population of 17,950 people and an average household size of 2.33 people (U.S. Census Bureau, 2010). Adding 160 dwelling units would add approximately 370 people, which is within the 20,000-person high projection for 2020.

5.4 Future Water Demand

DBS&A developed two projections of future water demand for the LACWU for 2020 through 2060. The projections are based on (1) the population projections developed as a part of the State of New Mexico's regional water plan update project (Poster Enterprises, 2014), (2) the total water system per capita demand for 2014 (LACWU, 2015), and (3) a separate water demand forecast that was provided by LANL (Ballesteros Rodriguez, 2016). The demand projections are shown on Table 5-9 and Figures 5-5 and 5-6. Total projected demand ranges between 3,634 and 4,841 ac-ft/yr, with the low projection showing an increase in demand between 2020 and 2030 and decreasing demand between 2030 and 2060, and the high projection showing increasing demands throughout the 40-year time frame.

The previous long-range water supply plan recommended an initial minimum goal of a 12 percent reduction in water demand (DBS&A, 2006). This was one of the long-term goals developed for the LACWU's fiscal year 2013 planning, and it was approved by the Utility Board on September 18, 2013 (Alarid, 2015). Comparing the 2006 water diversions to the more current data, this goal was met by 2014 (Table 5-1), when total diversions were 13 percent less than in 2006. Los Alamos County has a robust water conservation program (Section 8) and recently published an update to the *Energy and Water Conservation Plan* (LACWU, 2015). Further reductions in per capita demand are expected; however, to help compensate for the uncertainty of the LANL projections and ensure that the County plans for adequate future supply, further reductions in demand that may result from conservation have not been incorporated into the water demand projections **that are shown on Table 5-9 and Figures 5-5 and 5-6**.

LANL provided a 10-year water demand forecast, spanning the period of fiscal year 2017 to 2027 (Table 5-8). For the projections beyond 2027, to 2060, LANL demand was assumed to

DRAFT

remain at the fiscal year 2027 volume. LANL also provided projections for the volume of water to be pumped as part of the chromium interim measure project. As discussed in Section 4.1.1, an application for permit to change an existing water right was filed jointly by DOE and the LACWU in May 2016, in support of the chromium interim measure project that will run through December 2023 (Rodriguez, 2016), and emergency authorization was received on September 10, 2016 (NMOSE, 2016). The volume of water for this application is 679 ac-ft/yr (U.S. DOE and LACWU, 2016). In the absence of any estimates for the volume of water that will be needed to support the future chromium remediation project, the chromium interim measure volume is assumed to be needed through 2060. This volume has not been included in the water demand projections (Table 5-9), as the water will be pumped separately and will not be supplied by the LACWU. Figures 5-5 and 5-6 present the low and high water demand projections and illustrate the LACWU and DOE water rights volumes including and excluding the volume needed for the chromium interim measure project. The projections assume that the water supply remains available in terms of water rights and contamination**, and do not take into account the possibility of treating and using contaminated groundwater, which would be possible (with public support)**.

Table 5-10 presents a range in conservation savings that could be achieved with further reductions in the LACWU's 2014 per capita demand of 135 gpcd, ranging from a 5-gpcd savings to a 45-gpcd savings (the reduction necessary to match the City of Santa Fe's 2015 per capita value of 90 gpcd). Achieving the City of Santa Fe's 2015 per capita value would be equivalent to a water conservation savings of between 800 and 1,114 acre-feet per year, based on the population projections for 2060.

Table 5-10. Potential Water Conservation Savings

Per Capita Water Use (gpcd)	Reduction from 2014 Per Capita Use (%)	Annual Conservation Savings: Low Population Projection (acre-feet) [a]	Annual Conservation Savings: High Population Projection (acre-feet) [a]
130	4	89	124
120	11	267	371
110	19	444	619

DRAFT

Per Capita Water Use (gpcd)	Reduction from 2014 Per Capita Use (%)	Annual Conservation Savings	
		Low Population Projection (acre-feet) [a]	High Population Projection (acre-feet) [a]
100	26	622	866
90 [b]	33	800	1,114

[a] Annual water conservation savings that would be achieved based on reductions from the 2014 per capita value of 135 gallons per day in 2060.
[b] This value is equivalent to the City of Santa Fe's per capita demand in 2015.

Figures 5-7 and 5-8 show low and high water demand projections, assuming that the LACWU water demands are reduced in the future due to conservation (the LANL water demands remain unchanged). Table 5-11 shows the data that are plotted on Figures 5-7 and 5-8. The same low and high population projections that are used for Figures 5-5 and 5-6 have been used for both scenarios, but the per capita demand is assumed to be reduced from 135 gpcd (the 2014 value) to 130 gpcd by 2030, 120 gpcd by 2040, 110 gpcd by 2050, and 100 gpcd by 2060.

6. Reconciliation of Supply with Demand

To ensure that adequate water resources are available to meet future demands, the LACWU must take into consideration the quantity of supply available, limitations to the supply due to water quality concerns, and the legal ability to use the available supply (water rights).

The physical water supply is discussed in detail in Section 3. Given the amount of water in storage and the large saturated thickness in relation to observed rates of water level decline, and assuming that the LACWU remains the primary diverter in the area, the LACWU is expected to have an adequate quantity of supply to meet the projected demands over a 40-year time frame. Wells may need to be replaced or moved to new locations, but it is expected that the available supply somewhere in the vicinity of Los Alamos will be adequate to fulfill the LACWU's existing water rights. Ongoing monitoring of water levels and aquifer testing is recommended to confirm that threats to water supply do not develop.

As discussed in Section 3.2.2, there is some risk to the supply due to contamination, and if the LACWU's supply wells were to be impacted, they could become unusable over the 40-year plan horizon **(without treatment)**. The hexavalent chromium plume near several supply wells will continue to be monitored as the interim measure is implemented, and the presence of this contamination highlights why contingency planning for potential impacts to water supply wells is important.

If contaminant levels exceed applicable standards in any supply well, the LACWU could potentially redrill the well in an alternate location and continue to pump the same volume, provided that the transfer of the diversion point is approved by the OSE. Potential locations for replacement wells have not been identified, but the best locations would be upgradient from contaminant sources, accessible to existing water supply infrastructure, in productive zones, and separate from the influence of other pumping wells. The LACWU filed an application for an additional point of diversion (O**towi Well No. -**2) on April 28, 2016. This well will be drilled to supplement the system's existing production wells in anticipation of declining production rates from existing wells that are nearing the end of their service life (Alarid, 2016), rather than as a replacement well for any future contamination of well(s) that could occur.

DRAFT

As discussed in Section 4.1.1, DOE owns 30 percent (1,662.39 ac-ft/yr) of the total groundwater rights (5,541.3 ac-ft/yr), and the long-term lease that was in place for LACWU to use these water rights expired in 2011. A portion of the volume of the DOE-owned water rights (679 ac-ft/yr) will be used for the chromium interim measure project**; however,** ~~, and~~**the** LACWU **is pursuing**~~plans to~~ **a** lease **for** the ~~remaining~~ **full** DOE**-owned water rights volume**~~ water rights~~ (**1,662.39**~~983.39~~ ac-ft/yr)**.**~~;~~ ~~however, t~~**T**he lease is not yet in place. If DOE declines to lease their water rights to the LACWU, the groundwater rights volume that the LACWU has access to will be reduced to 3,878.91 ac-ft/yr.

The LACWU-owned groundwater rights volume **(3,878.91 ac-ft/yr)** is not adequate to meet the LACWU plus LANL low-water-use projections for 2030, 2040, 2050, or 2060, but the 2020 low-water-use projections can be met with this volume (Figure 5-5). The LACWU-owned groundwater rights volume is not adequate to meet any of the LACWU plus LANL high-water-use projections (Figure 5-6). **With increased conservation in the amounts shown on Table 5-11, the LACWU-owned groundwater rights volume is not adequate to meet the LACWU plus LANL low-water-use projections for 2030, but the 2020, 2040, 2050, and 2060 low-water-use projections can be met with this volume (Figure 5-7). With increased conservation, the LACWU-owned groundwater rights volume is not adequate to meet any of the LACWU plus LANL high-water-use projections (Figure 5-8).** In the event that the remaining DOE water rights are not leased to the LACWU**,**~~ and~~ the LACWU continues to be the sole water provider for LANL, **and the high population projections are realized, even with significant additional conservation** the LACWU will need to implement a project to bring their San Juan-Chama **Project** water online. Additional discussion of contaminant and water rights risks is presented in Sections 3.2.3 and 4.3, and recommendations for responding to these risks are discussed in Section 9.

As discussed in Section 5.4, both low- and high-water-use projections were developed based on LACWU and LANL growth projections made for the current regional water plan updates. To evaluate the gap between the projected demands and the available supply, two scenarios were considered, as discussed in Sections 6.1 and 6.2.

6.1 Scenario 1: Low-Water-Use Projection and Supply Available to Fulfill Water Rights

The total (LACWU plus LANL) projected water use under the low-water-use scenario is estimated to increase from the actual 2010 water demand of 3,616 ac-ft/yr to 3,634 ac-ft/yr in 2020 and 4,191 ac-ft/yr in 2030 and then decrease to 3,900 ac-ft/yr by 2060 (Table 5-9, Figure 5-5). In this scenario, total projected demand can be met by the existing groundwater rights, assuming that the LACWU will lease the DOE groundwater rights ~~that will not be used for the chromium interim measure project~~. The total low-water-use projections are less than the volume of LACWU- and DOE-owned groundwater rights remaining after subtracting the volume that will be used for the chromium **interim measure** project (4,862.3 ac-ft/yr). It is also assumed that the LACWU can continue to produce water under these water rights, recognizing that either treatment or moving of wells to alternate uncontaminated locations may be required to fulfill those water rights.

6.2 Scenario 2: High-Water-Use Projection and Loss of Water Rights

The total (LACWU plus LANL) projected water use under the high-water-use scenario is estimated to increase to 3,938 ac-ft/yr by the year 2020 (Table 5-9, Figure 5-6) and to further increase to 4,841 ac-ft/yr by 2060. In this scenario, total projected demand can be met by the existing groundwater rights, assuming that the LACWU will lease the DOE groundwater rights ~~that will not be used for the chromium interim measure project~~. The total high-water-use projections are less than the volume of LACWU- and DOE-owned groundwater rights remaining after subtracting the volume that will be used for the chromium **interim measure** project (4,862.3 ac-ft/yr); however, the projected water demand in 2060 is within 21.3 ac-ft/yr of this water rights volume.

As discussed in Section 4.3.2, there is some risk that if wells need to be moved or other changes are needed that require OSE approval, additional water rights may be required to offset pumping impacts on the Rio Grande. If additional water rights could not be purchased and transferred to the Los Alamos area, a potential scenario given extended drought conditions and other growth pressures on the Rio Grande, the San Juan-Chama **Project** water rights might need to be used to offset pumping effects, in which case physical diversion of the San Juan-Chama **Project** water would not be possible.

In the event that ~~This scenario envisions a situation where~~ a portion of the groundwater supply is contaminated, ~~necessitating the relocation of~~ 1,200 acre-feet of groundwater diversions **will need to be relocated and** ~~. The scenario further assumes that~~ the OSE **will** require the impacts to the Rio Grande to be offset in an amount equal to the production of the new wells**. To meet this requirement,** ~~necessitating the use of~~ San Juan-Chama **Project** water **would be needed** ~~in an equal amount~~ to offset the pumping. ~~In effect, the groundwater rights would be diminished.~~

The high water demand projection with a loss of water rights scenario assumes that the LACWU will lease the **full volume of** DOE groundwater rights**, and that the volume** ~~that will~~ not be**ing** used for the chromium interim measure project **will be available for use**. Under this scenario, there is a gap between the diminished groundwater supply and projected demand starting in 2030 that would need to be addressed, either by bringing the San Juan-Chama Project water online or through reductions in demand (water conservation). Taking into account the volume of DOE groundwater rights that will be used to support the LANL chromium interim measure project, this gap reaches **1,146**~~500~~ ac-ft/yr by 2060 ~~(Figure 6-1)~~.

DRAFT

7. Climate Change

One of the goals of the LACWU water resource planning effort is anticipating and preparing for potential climate change impacts. For water resources planning, it is important to understand both natural variations in climate and variations that may result from anthropogenic climate change. This section includes information on natural climate variability (Section 74.1), anticipated changes in temperature and precipitation due to climate change (Section 74.2), potential impacts of climate change in the Los Alamos area (Section 74.3), and recommendations for mitigating climate change impacts (Section 74.4).

7.1 Natural Climate Variability

The climate of Los Alamos County naturally exhibits variability in precipitation and temperature, including both seasonal and annual variations. Weather patterns in the southwestern United States, including the Los Alamos area, are affected by several natural cycles:

- *El Niño/La Niña:* El Niño and La Niña are characterized by unusually warm and unusually cool temperatures, respectively, in the equatorial Pacific. Years in which El Niño is present are more likely to be wetter than average in New Mexico, and years with La Niña conditions are more likely to be drier than average.

- *The Pacific Decadal Oscillation (PDO):* The PDO is a long-lived pattern of climate variability caused by shifting sea surface temperatures between the eastern and western Pacific Ocean that cycle approximately every 20 to 30 years. Warm phases of the PDO (shown as positive numbers on the PDO index) correspond to El Niño-like temperature and precipitation anomalies (i.e., wetter than average), while cool phases of the PDO (shown as negative numbers on the PDO index) correspond to La Niña-like climate patterns (drier than average). It is believed that since 1999, Los Alamos County has been in the cool phase of the PDO.

- *The Atlantic Multidecadal Oscillation (AMO):* The AMO refers to variations in surface temperatures of the Atlantic Ocean which, similarly to the PDO, cycle on a multi-decade frequency. The pairing of a cool phase of the PDO with the warm phase of the AMO is typical of drought in the southwestern United States (McCabe et al., 2004; Stewart, 2009). The AMO has been in a warm phase since 1995 and it is possible that the AMO may be shifting to a cool phase, but the data are not yet conclusive. LANL has been doing statistical analyses to evaluate the correlation between the AMO and warming temperatures and has concluded that anthropogenic effects account for two-thirds of the post-1975 global warming, while the AMO accounts for one-third of the effect (Chylek et al., 2014).

These natural cycles and other short-term meteorological conditions lead to considerable annual and monthly variability in temperature and precipitation.

7.2 Changes in Temperature and Precipitation

In addition to the natural variability in temperature and precipitation, there is significant research indicating that long-term trends, particularly in temperature, are changing. The Intergovernmental Panel on Climate Change (IPCC) is an international body that was created to assess the science related to climate change world-wide. The IPCC's most recent research efforts are summarized in the Fifth Assessment Report, which was released in September 2013.

IPCC assessments are prepared and reviewed by hundreds of scientists and provide a scientific basis for governments at all levels to develop policies related to climate change. The Fifth Assessment report indicates that globally the atmosphere and oceans have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased (IPCC, 2013). Atmospheric concentrations of greenhouse gases are rising so quickly that all current climate models project significant warming trends over continental areas in the 21st century. The IPCC report also suggests that it is extremely likely that more than half of the increase in annual surface temperature from 1951 to 2010 is explained by anthropogenic increases in greenhouse gases and other anthropogenic forcings (IPCC, 2014). Likely impacts of climate change include increased numbers of dry days and extreme events (IPCC, 2012).

In the United States, regional assessments conducted by the U.S. Global Change Research Program (USGCRP, 2015) have found that temperatures in the southwestern United States have increased and are predicted to continue to increase. Reduced snowpack and streamflow and increased drought and wildfires are anticipated impacts of climate change in the southwest (USGCRP, 2015). Recent flows in the Upper Colorado and Rio Grande were 3 to 5 percent lower during 2001 through 2010 than 20th Century average flows, and snowmelt occurred earlier (Overpeck et al., 2013).

To assess climate trends in New Mexico, the NMOSE and NMISC (2006) conducted a study of observed climate conditions over the century and found that observed wintertime average temperatures had increased statewide by about 1.5 degrees Fahrenheit (°F) since the 1950s.

More recently, the U.S. Bureau of Reclamation, with technical assistance from Sandia National Laboratories and the U.S. Army Corps of Engineers, conducted a study of the Upper Rio Grande that evaluated climate impacts in northern New Mexico (USBR, 2013). The study, entitled the Upper Rio Grande Impact Assessment (URGIA) found that average temperatures from 1971 through 2011 rose at a rate of approximately 0.7°F per decade, approximately twice the global average, for a total warming of approximately 2.5°F since 1971. Temperatures are predicted to rise an additional 4° to 6°F by the end of the century. The study additionally projected a decrease in native Rio Grande water by about a third and a decrease in tributary flow by about a quarter, increasing frequency, intensity, and duration of droughts and floods, earlier snowmelt runoff, and increased variability in the magnitude, timing, and spatial distribution of streamflow and other hydrologic variables.

A number of other studies predict temperature increases in New Mexico from 5° to 10°F by the end of the century (Forest Guild, 2008; Hurd and Coonrod, 2008; USBR, 2011).

Although there is consensus among climate scientists that global temperatures are warming, there is considerable uncertainty regarding the specific local and temporal impacts that can be expected. Predictions of annual precipitation are also subject to uncertainty, particularly regarding precipitation during the summer monsoon season in the southwestern U.S.

While attribution of individual events remains a challenge, droughts and heavy short-term precipitation in the Southwest are predicted to be more severe as human-induced climate change progresses (USGCRP, 2014). An example of extreme precipitation events occurred in September 2013 in Boulder, Colorado, where a 3-day rainfall exceeded the monthly total for any month on record and was classified as a 1,000-year event (chance of 1 in 1,000 of occurring) (NOAA Climate.gov, 2013). During the same September 2013 time period, the Los Alamos area also experienced extreme precipitation. Initial research indicates that the extreme events that occurred in Colorado in 2013 were not due to anthropogenic climate change (NOAA Climate.gov, 2014). Since extreme events occur infrequently, however, it is difficult to observe trends and conclusively attribute causes.

7.3 Impacts of Climate Change on Los Alamos County

Climate change impacts that are likely to occur in Los Alamos County based on studies of the Southwest and New Mexico in particular (Christensen et al., 2004; Hurd and Coonrod, 2008; NMOSE/NMISC, 2006; Overpeck et al., 2013; USBR, 2011, 2013; USGCRP, 2015; Williams et al., 2010) include:

- Though model predictions vary, increasing temperatures are expected to occur. Warming will continue with longer and hotter heat waves during summer months.

- Higher temperatures will result in a longer and warmer growing season, resulting in increased water demand for outdoor watering during the spring and summer months and potentially lower rates of recharge.

- Reservoir and other open water evaporation is expected to increase. This could affect the non-potable water in storage in Los Alamos Reservoir and could potentially lead to shortages of San Juan-Chama **Project** water.

- Although predictions of annual precipitation are subject to greater uncertainty "given poor representation of the North American monsoon processes in most climate models" (NMOSE/NMISC, 2006), precipitation is expected to be more concentrated and intense, so increases in the frequency and severity of flooding are projected. Due to the presence of various contaminated areas around Los Alamos due to historical LANL operations, stormwater management is a key issue for the LACWU and LANL.

- Streamflow in major rivers across the Southwest is projected to decrease ~~substantially~~ during this century, due to a combination of diminished cold season snowpack in the headwaters regions and higher evapotranspiration during the warm season. **The U.S. Bureau of Reclamation developed projections of the hydrologic impacts of modeled climate changes for the Upper Rio Grande Basin over the rest of this century and published their results in the Upper Rio Grande Impact Assessment (USBR, 2013). Their analysis included the reliability of the San Juan-Chama Project water under potential climate change scenarios. The projections suggest an increase in the month-to-month and inter-annual variability, and a somewhat more reliable supply from the San Juan-Chama Project than for the native Rio Grande supply (USBR, 2013). The results for the average total San Juan-Chama allocations were 94 percent of contracted water rights in the 2020s, 88 percent in the 2050s, and 81 percent in the 2090s (USBR, 2013), indicating that the average total San Juan-Chama Project allocation would be reduced by about 20 percent by the 2090s (USBR, 2013). To account for the**~~There is a~~ potential for reduced streamflow to result in shortages of San Juan-Chama **Project** water in some years, ~~indicating~~ **San Juan-Chama Project water**~~that it~~ should be conjunctively managed with more reliable groundwater resources.

- The seasonal distribution of streamflow is projected to change as well: flows could be somewhat higher than at present in late winter as warmer conditions lead to more winter precipitation falling as rain and less as snow, but peak runoff will be weaker due to reduced snowpack. Late spring/early summer flows are projected to be much lower than at present, given the combined effects of less snow, earlier melting, and higher evaporation rates after snowmelt. Since the LACWU relies primarily on groundwater, this is not anticipated to present a major concern for LACWU water resources, but these pressures may lead to overall added stress on the Rio Grande systems, which may increase vulnerability to administrative changes in junior water rights management, as discussed in Section 4 and by Kenney et al. (2008).

During the period of observed record, the Southwest has experienced two significant dry periods, the 1950s and the early 2000s, with the second drought period being warmer and producing greater water loss. The 1980s and 1990s were wetter and promoted a lot of vegetation growth, creating conditions of higher vulnerability to forest fire (NOAA, 2013). The extreme drought conditions prevalent throughout New Mexico and Los Alamos in the past 10 years have resulted in the mortality of many trees. Between 2002 and 2005, more than 90 percent of the mature piñon trees in the Los Alamos area died from a combination of drought stress and bark beetle infestation (Breshears et al., 2005, as cited in LANL, 2014a). Lower-elevation ponderosa pine and mixed conifer stands were also affected. More recently, large numbers of mature ponderosa pine are dying, apparently due to prolonged drought stress. These conditions lead to vulnerability to wildfire and post-fire flooding.

Los Alamos County has already experienced extreme wildfires and post-fire flooding since 2000:

- The Cerro Grande fire burned 47,000 acres in May 2000. The fire started as a result of controlled burning in Bandelier National Monument and directly impacted structures and vegetation in the Los Alamos area.

- The Las Conchas wildfire started on June 26, 2011 in the Jemez Mountains, approximately 10 miles west of Los Alamos, and ultimately burned approximately 156,600 acres, making it the largest wildfire in New Mexico history at the time. Fire damage in the upper portions of watersheds above Los Alamos greatly increased the risk of flash floods and flood damage in the downstream canyons (LANL, 2014a).

- On September 13, 2013, anywhere from 2.49 to 3.52 inches of rain fell at different locations around Los Alamos within a 24-hour period. All of the local canyons flooded, and some experienced substantial channel and bank erosion and widespread sediment deposition. Infrastructure, including roads, gaging stations, and other sampling equipment, was also significantly damaged (LANL, 2014a). With saturated antecedent soil conditions caused by a previous storm on September 10, the flooding that occurred during the September 12 to 13 storm damaged LANL's environmental monitoring and control infrastructure, including access roads, groundwater monitoring wells, gaging stations, and watershed controls. The damage to or impairment of flood- and sediment-control structures included a large amount of erosion in the Pueblo Canyon Wetlands, and overflow from sediment traps and retention basins in other canyons. LANL has since installed various sediment-control structures to minimize the erosive nature of stormwater runoff and to enhance deposition of sediment.

As discussed previously, while it may be difficult to determine if a specific event is caused by climate change, these are the types of impacts that the LACWU needs to continue to plan for.

7.4 Recommendations for Mitigating Impacts of Climate Change

Though it is difficult to determine whether individual events are a result of natural climate variability or climate change, it is important for the LACWU to be prepared to address variability, including drought and extreme precipitation events, and to be aware that these conditions may be both more frequent and more severe as a result of climate change. Higher temperatures and drought may contribute to increased demands for water, diminished supplies, impacts to vegetation, and wildfire risk. Extreme precipitation may damage infrastructure due to stormwater runoff and flooding, mobilize surface or shallow contaminants due to erosion, and create extreme sedimentation that can affect reservoir storage, as has occurred at Los Alamos Reservoir following the Cerro Grande and Las Conchas fires.

The following are recommendations that the LACWU could implement to prepare for long-term and severe drought, as well as for extreme precipitation events:

- Implement adaptive management as a part of the long-range water supply plan, where decisions are made sequentially over time, allowing adjustments to be made as more information is known. This approach may be useful in dealing with the additional uncertainty introduced by potential climate change.

DRAFT

- Use research and monitoring to fill knowledge gaps and enhance planning capabilities. Although neither will eliminate all uncertainty, they will provide significant improvements in understanding the effects of climate change on water resources and in evaluating associated uncertainties and risks required for more informed decision making (Brekke et al., 2009).

- Continue to implement and update the Los Alamos Energy and Water Conservation Plan to help reduce outdoor demands during periods of drought and to use water resources efficiently during all times.

- Conjunctively manage surface and groundwater resources. It will be important to bring surface water from Los Alamos Reservoir (and potentially ~~the~~ San Juan-Chama **P**~~p~~roject **water**) online, allowing for conservation of groundwater resources during times when surface water is available, while having provisions for meeting demand with groundwater during extreme drought periods when surface water is not available.

- Prepare for the increasing risk of large and severe wildfires. The LACWU should work with U.S. Forest Service and New Mexico State Forestry Division personnel to identify particular fire risks and vulnerabilities. Ponderosa pine and Douglas fir are particularly susceptible to drought and rising temperatures (Williams et al., 2010). An important component of wildfire planning is to work with emergency personnel on a plan to protect critical drinking water infrastructure during potential fires. The LACWU should also coordinate with LANL on its efforts to mitigate the effects of potential wildfires:

  – LANL operates a program to reduce wildfire fuels and manage forest health throughout forested areas on Laboratory and DOE property. Defensible space is created and maintained around facilities and other high-priority areas, and areas not designated as defensible space are managed for a combination of wildfire fuel reduction and forest health. The major roads within the facility continue to be thinned along the road easements to the fencelines, to provide firebreaks and improve vehicle visibility to wildlife crossing the roads (LANL, 2014a).

– Following the Los Conchas fire in 2011, high-priority areas in the canyons were armored to protect against potential flood damage (LANL, 2014a).

The U.S. EPA published the 2013 Draft National Pollutant Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Industrial Activities, also referred to as the Multi-Sector General Permit (MSGP), by Federal Register (FR) notice on September 27, 2013 (78 FR 59672). The MSGP requires the implementation of control measures, development of stormwater pollution prevention plans (SWPPPs), and monitoring of stormwater discharges from permitted sites. LANL conducts stormwater sampling and has implemented some flood mitigation measures. LACWU should continue to work with LANL to mitigate the risk of extreme precipitation events and flooding mobilizing contamination, which could affect the drinking water system.

Climate change modeling for the Southwest is based on varying carbon emissions scenarios, with higher rates of warming predicted with higher emissions. While Los Alamos County alone cannot significantly change regional emissions, the LACWU can contribute to reduced emissions through its energy policies, as discussed in the *Energy and Water Conservation Plan* (LACWU, 2015).

8. Water Conservation

The existing long-range water supply plan (DBS&A, 2006) included a water conservation plan, and additional documents that address water conservation have been published since that time. The LACWU published an *Energy and Water Conservation Plan* in 2013 (LACWU, 2013a), and this document was revised and reissued in 2015. The updated *Energy and Water Conservation Plan* focuses on conservation goals for the planning period of 2015 through 2019 (LACWU, 2015), and it meets the requirements of the New Mexico *Water Conservation Planning Guide for Public Water Suppliers* (NMOSE, 2013). The plan includes a water audit covering fiscal year 2014 (July 1, 2013 through June 30, 2014) (Section 5, Table 5-6), as well as the completed GPCD calculator worksheets covering 2007 through 2014 (LACWU, 2015).

~~The LACWU has a full-time conservation coordinator position, responsible for public outreach, program implementation and monitoring, and future document revisions.~~ The conservation program is implemented by customers primarily on a voluntary basis and the goals are not directed toward LANL, which falls outside of the County's jurisdiction (LACWU, 2015).

Existing water conservation program activities that are discussed in detail in the 2015-2019 Energy and Water Conservation Plan (LACWU, 2015) include:

- *Customer meter testing and replacement.* The LACWU routinely tests customer meters and replaces those that are not working properly; in FY 2015, the program goal called for replacing 350 residential water meters.

- *Large water customer usage and account review.* The LACWU completed a large water meter review project in 2011 that addressed discrepancies in the billing or metering of large customers.

- *System leak detection surveys.* The LACWU surveys 20 percent of the water system annually in an effort to identify and fix water leaks.

- *Regulatory measures.* The Los Alamos Board of Public Utilities adopted Water Rule W-8 in 2005 to prohibit water waste and implement the even/odd address watering schedule, daytime watering restrictions, and leak repair requirements.

- *Water rates.* The Los Alamos County Council approved a tiered water rate structure in July 2014 for the LACWU's single-family and multi-family residential customers.

- *County park irrigation water audits.* The LACWU **has** work**ed**~~s~~ with the County parks to conduct irrigation audits, ~~to~~ recommend irrigation scheduling and maintenance, and ~~to~~ identify any leaks or problems. ~~Baseline water use is being determined for each park, so that park managers are able to analyze trends in water use after the audit has been completed.~~ The Los Alamos County Sustainability Plan includes a goal of reducing water demand for County parks by 25 percent ~~compared to~~**of** 2012 demand by 2020 (LACWU, 2013b).

- *Residential water leak training and audits*. The LACWU participates in the nationally advertised "Fix a Leak" week, offering fix a leak demonstrations and providing water audits for high water using customers.

- *Commercial water audits.* The LACWU conservation coordinator implemented a commercial water audit program in 2012, initially conducting seven audits on facilities including a hotel, grocery store, and school campus. The program is ongoing, and each participating facility is provided with a detailed report of the audit findings and recommendations.

- *Residential water conservation outreach.* Educational materials are distributed to LACWU customers through bill inserts, feature articles, workshops, and booklets on subjects including graywater use, rainwater harvesting, xeriscape and permaculture, and energy efficiency.

- *Public school outreach.* Since 2008, the LACWU has had a contract with the Pajarito Environmental and Education Center (PEEC) to perform energy and water conservation outreach in the public schools.

- *Conservation partnerships.* The LACWU participates in numerous regional and national conservation partnerships in order to share ideas, resources, and lessons learned. Existing partnerships include EPA WaterSense (promotional partner), Alliance for Water Efficiency (charter member), New Mexico Water Conservation Alliance (member), U.S. EPA Energy Star (promotional partner), Alliance to Save Energy (member), and Los Alamos Sustainability Program (participant).

- *Residential bill revisions.* The LACWU implemented changes to the residential customer bills in 2012, and customer bills now show usage for the past 13 months, allowing for comparison of usage between the current month and the previous year. Additional revisions are being planned.

A Conservation Advisory Group was formed in 2011 ~~to assist the LACWU conservation coordinator with the development of conservation goals.~~ **and** ~~The group~~ has eight members, representing the Los Alamos Public Schools, County Parks Division, County Environmental Services Division, small commercial customers, and residential customers (LACWU, 2015). The long-term goal of the water conservation program is to achieve a 12 percent reduction in per capita water demand by 2050, as approved by the Utility Board on September 18, 2013 (Alarid, 2015). Specific actions that have been identified to assist in meeting this goal include:

- Increase water conservation education in the public schools.
- Increase adult education efforts, including outreach lectures and demonstration workshops.
- Implement residential irrigation water audits, focusing on customers with high summer water use.
- Improve Water Rule W-8 by researching its effectiveness, revising as necessary, and potentially adding enforcement capabilities.

- Implement incentives for replacement of lawns, including rebates for plant purchases and technical assistance.
- Implement the county's non-potable water master plan (Forsgren & Associates, 2013), which presents water use criteria for evaluating the efficiency of the existing non-potable water systems and for additional sites that could be potentially served by one of the non-potable water systems in the future.

The LACWU monitors the success and implementation of the Energy and Water Conservation Program annually, using activities such as evaluating data from the Cayenta billing system, completing the OSE GPCD calculator, and using the Alliance for Water Efficiency tracking tool~~. The LACWU conservation coordinator updates the Board of Public Utilities on the program's activities on a quarterly basis~~ (LACWU, 2015).

9. Recommendations

The LACWU is planning for potential future growth and increased water demands. While the groundwater supply will likely continue to produce at current rates for well beyond the 40-year planning period, issues regarding water rights and potential water quality concerns indicate that the LACWU needs to proactively plan for the future. A summary of recommendations for addressing the future water supply needs of the LACWU follows.

Water Supply (Quantity)

- Monitor water levels in the vicinity of the water supply wells and evaluate declines on a regular basis, with particular emphasis on monitoring the Guaje well field. Static water levels should also be measured in each of the active production wells on at least an annual basis.

- **Continue to examine project options and initiate an environmental assessment for San Juan-Chama Project water utilization**~~Initiate an environmental assessment for the San Juan-Chama Project~~, and evaluate whether to initiate steps toward implementation, based on the water demand projections and supply-demand gap estimates presented in this ~~report~~**plan**. Bringing the San Juan-Chama Project water online would help the LACWU address the potential for contamination of the existing wells by diversifying the water supply **both geographically and in terms of water rights**.

Water Quality/Contaminant Risk Recommendations

- Work closely with LANL and NMED regarding the ongoing monitoring of contaminants and assessment of anticipated transport velocities and flow paths, especially relating to the chromium interim measure and future remediation projects.

- Evaluate contaminant data on a quarterly basis to identify any trends or changes.

- Begin contingency planning for alternate well locations. In a worst case scenario, many wells could be affected by contaminants over the planning period. To prepare for this contingency, identify possible locations for new wells that are upgradient from or off-gradient of key source areas, and begin to resolve infrastructure, land access, and water rights transfer issues so that alternative wells could be developed in a timely manner.

- To mitigate potential climate change impacts, work with emergency personnel to develop a plan to protect drinking water infrastructure in the event of a wildfire, and work with LANL to prepare for extreme precipitation events, to ensure that stormwater runoff does not mobilize contaminants to the detriment of the drinking water system.

Water Rights

- Pursue a new lease with DOE for ~~the portion of~~ their water rights ~~that will not be used by the chromium interim measure project~~ (~~983.39~~**1,662.39** ac-ft/yr).

- Renegotiate the contract that LACWU has with DOE for supplying water to LANL before it expires in 2019.

- Secure services of a water rights attorney to advise and plan for water rights acquisition (availability of pre-1907 water rights, return flow credits, costs, time to secure, potential litigation).

- Pursue return flow credits as identified in the 1999 return flow study (SWC, 1999).

- Evaluate and quantify pumping effects on the Rio Grande from the current water production regime and explore potential changes in pumping amounts and locations in order to be prepared to address OSE concerns during a potential water rights transfer application process.

- Meet with the OSE to discuss priority administration and the number and amount of water rights that are senior to the LACWU's water rights.

Water Conservation

- Continue and expand the existing water conservation program, as discussed in Section 8, monitoring the effectiveness of the existing and new conservation measures and refining the conservation program as needed.

- Monitor the effectiveness of voluntary compliance with Rule W-8 in reducing water waste, and if necessary, pass an enforceable ordinance so that penalties can be assessed.

- Update the subdivision regulations to include requirements for graywater reuse, water harvesting, xeriscaping, and low-water-use indoor plumbing for all new commercial and residential development.

- Establish rebate programs for xeriscaping and appliance replacement.

- Distribute indoor plumbing leak detection and retrofit kits.

Implementation of these recommendations will help the LACWU be prepared to meet its future water supply needs.

References

Alarid, J. 2015. E-mail from James Alarid, Los Alamos County Water Utility Deputy Utility Manager, Engineering Division, to Amy Ewing, Daniel B. Stephens & Associates, Inc. June 16, 2015.

Alarid, J. 2016. E-mail from James Alarid, Los Alamos County Water Utility Deputy Utility Manager, Engineering Division, to Amy Ewing, Daniel B. Stephens & Associates, Inc. June 14, 2016.

Anderholm, S.K. 1994. *Groundwater recharge near Santa Fe, north-central New Mexico.* Water Resources Investigations Report 94-4078. United States Geological Survey, Reston, Virginia.

Baer, T. 2016. E-mail from Tamara Baer, Los Alamos County Community Development Department, to Gaylyn Meyers, Los Alamos County Water Utility Engineering Project Manager. September 6, 2016.

Ballesteros Rodriguez, S. 2016. E-mail from Sonia Ballesteros Rodriguez, LANL Utilities and Institutional Facilities Sustainability Group Lead Analyst, to Cassandra Begay, U.S. Department of Energy, Los Alamos Field Office, Utilities Program Manager, transmitting LANL 10-year water demand projection. October 14, 2016.

Birdsell, K.H., B.D. Newman, D.E. Broxton, and B.A. Robinson. 2005. Conceptual models of vadose zone flow and transport beneath the Pajarito Plateau, Los Alamos, New Mexico. *Vadose Zone Journal* 4(August 2005):620-636.

Brekke, L.D., J.E. Kiang, J.R. Olsen, R.S. Pulwarty, D.A. Raff, D.P. Turnipseed, R.S. Webb, and K.D. White. 2009 *Climate change and water resources management—A federal perspective.* U.S. Geological Survey Circular 1331. 65p. Available at <http://pubs.usgs.gov/circ/1331>.

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J. H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers and C.W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. *Proceedings of the National Academy of Sciences* 102(42):15144-15148 (2005).

Broxton, D.E., and D.T. Vaniman. 2005. Geologic framework of a groundwater system on the margin of a rift basin, Pajarito Plateau, north-central New Mexico. *Vadose Zone Journal* 4(August 2005):522-550.

Bureau of Business and Economic Research (BBER). 1996. *Population levels and trends in nine New Mexico water planning regions: 1960-2060.* Prepared for the New Mexico Interstate Stream Commission. University of New Mexico, Albuquerque, New Mexico. December 1996.

BBER. 2000. Population projections for the Jemez y Sangre water planning region. University of New Mexico, Albuquerque, New Mexico. November 2000.

BBER. 2012. Population projections by New Mexico county. University of New Mexico, Albuquerque, New Mexico. November 2012.

Cartron, D., J.W. Utton, and E. Atencio. 2002. *Alternative: Transfer water across Otowi Gage.* White paper prepared for the Jemez y Sangre Water Planning Region. July 2002. Available at <~~http://www.dbstephens.com/project_plans/88.pdf~~**http://www.dbstephens.com/uploads/directory/fc754183ef684878970c593c36661971/Transfer_Water_Across_Otowi_Gage_2.pdf**>.

Christensen, N.S. A.W. Wood, N. Voisin, D.P. Lettenmaier, and R.N. Palmer. 2004. The effects of climate change on the hydrology and water resources of the Colorado River Basin. *Climatic Change* 62:337–363. Available at <https://portal.azoah.com/oedf/documents/08A-AWS001-DWR/Supplemental_Beverly_et_al/20040000%20Christensen%20et%20al%20

DRAFT

Effects%20of%20Climate%20Change%20on%20Hydrology%20and%20Water%20 Resources_Colorado%20River%20B.pdf>.

Chylek, P. J.D. Klett, G. Lesins, M.K. Dubey, and N. Hengartner. 2014. The Atlantic Multidecadal Oscillation as a dominant factor of oceanic influence on climate. *Geophysical Research Letters* 41(5):1689–1697. <http://onlinelibrary.wiley.com/doi/10.1002/2014 GL059274/pdf>. March 2014.

CDM Smith. 2012. *San Juan – Chama water supply project, Final preliminary engineering report, Los Alamos County, NM.* September 2012.

Daniel B. Stephens & Associates, Inc. (DBS&A). 2006. *Long-range water supply plan, Los Alamos County.* Prepared for Los Alamos County Water Utility, Los Alamos, New Mexico. August 2006.

Forest Guild. 2008. Managing forests in the face of climate change: A summary of New Mexico Forestry and Climate Change Workshop on November 20, 2008 in Albuquerque, New Mexico. December 2008.

Forsgren & Associates. 2013. *Los Alamos County non-potable water system master plan.* September 2013.

Fruth, William H. 2004. *Creating a Sustainable Los Alamos.* Prepared for the Los Alamos, New Mexico First Town Hall, August 19, 20, and 21, 2004. POLICOM Corporation.

Griggs, R.L., and J.D. Hem. 1964. *Geology and groundwater resources of the Los Alamos area, New Mexico.* Water-Supply Paper 1753, United States Geological Survey, Reston, Virginia.

Hearne, G.A. 1985. *Mathematical model of the Tesuque aquifer system underlying Pojoaque River basin and vicinity, New Mexico.* Water-Supply Paper 2205, United States Geological Survey, Reston, Virginia.

Hurd, Brian and Julie Coonrod. 2008. *Climate change and its implications for New Mexico's water resources and economic opportunities.* Technical Report 45, New Mexico State University.

Intergovernmental Panel on Climate Change (IPCC). 2012. Summary for policymakers. *In* Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.), *Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change.* Cambridge University Press, New York, NY. Available at <http://www.ipcc.ch/pdf/special-reports/srex/SREX_FD_SPM_final.pdf>.

IPCC. 2013. *Climate change 2013, The physical science basis.* Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY. 1535p. Available at <http://www.ipcc.ch/report/ar5/wg1/>.

IPCC. 2014. *Climate change 2014, synthesis report: Summary for policymakers.* Available at <http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf>.

Katzman, D. 2015. E-mail from Danny Katzman, Los Alamos National Laboratory, to Amy Ewing, Daniel B. Stephens & Associates, Inc. June 12, 2015.

Katzman, D. 2016. E-mail from Danny Katzman, Los Alamos National Laboratory, to Amy Ewing, Daniel B. Stephens & Associates, Inc. August 25, 2016.

Keating, E.H. 2006. Personal communication from Elizabeth Keating, LANL, with Amy Lewis, April 27, 2006.

Keating, E.H., V.V. Vesselinov, E. Kwicklis, and Z. Lu. 2003. Coupling basin- and local-scale inverse models of the Espanola Basin. *Ground Water* 41(2):200-211.

Keating, E.H., B.A. Robinson, and V.V. Vesselinov. 2005. Development and application of numerical models to estimate fluxes through the regional aquifer beneath the Pajarito Plateau. *Vadose Zone Journal* 4(August 2005):653-671.

Kenney, D., R. Klein, C. Goemans, C. Alvord, and J. Shapiro. 2008. *The impact of earlier spring snowmelt on water rights and administration: A preliminary overview of issues and circumstances in the western States,* Final project report (review draft). September 3, 2008.

Koch, Richard J., and David B. Rogers. 2003. *Water Supply at Los Alamos, 1998-2001.* LA-13985-PR, Los Alamos National Laboratory. March 2003.

Kwicklis, E., M. Witkowski, K. Birdsell, B. Newman, and D. Walther. 2005. Development of an infiltration map for the Los Alamos area, New Mexico. *Vadose Zone Journal* 4(August 2005): 672-693.

Los Alamos County Water Utility (LACWU). 2013a. *Energy and water conservation plan.* Prepared by the Department of Public Utilities. Approved by the Board of Public Utilities on June 19, 2013.

LACWU. 2013b. *Los Alamos County draft sustainability plan.* January 10, 2013. Available at <https://www.losalamosnm.us/gogreen/Documents/Sustainability%20Plan%20Draft%20with%20Appendices.pdf>.

LACWU. 2014. Briefing report to the County Council: Update on the San Juan-Chama Project and 40-year water plan, Tim Glasco, Presenter. March 19, 2014.

LACWU. 2015. *2015-2019 Energy and water conservation plan.* Prepared by the Department of Public Utilities. Approved by the Board of Public Utilities on March 18, 2015.

Los Alamos County and U.S. Department of Energy (LAC and DOE). 2009. Award/Contract: DE-AC52-09NA28985, Los Alamos National Lab water services, October 1, 2009 thru September 30, 2019. September 2009.

Los Alamos National Laboratory (LANL). 1981. *Radiological survey of the site of a former radioactive liquid waste treatment plant (TA-45) and the effluent receiving areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, New Mexico,* Final report. Prepared for U.S. Department of Energy. DOE/EV-0005/30, LA-8890-ENV, Los Alamos National Laboratory. May 1981.

LANL. 1993a. *RFI work plan for Operable Unit 1082,* Final draft. LA-UR-93-1196, Los Alamos National Laboratory. July 1993.

LANL. 1993b. *RFI work plan for Operable Unit 1157.* LA-UR-93-1230, Los Alamos National Laboratory. July 1993.

LANL.1998. *Hydrogeologic workplan*. *Los Alamos National Laboratory, Los Alamos, New Mexico.* May 22, 1998.

LANL. 2005. *Los Alamos National Laboratory's hydrogeologic studies of the Pajarito Plateau: A synthesis of hydrogeologic workplan activities (1998-2004).* Report LA-14263-MS, Los Alamos National Laboratory, Los Alamos, New Mexico. December 2005.

LANL. 2006. *Los Alamos history.* <http://www.lanl.gov/history/overview.shtml> Accessed March 2006.

LANL. 2009. *Investigation report for Sandia Canyon.* LA-UR-09-6450 / EP2009-0516. October 2009. Available at <http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-09-06450>.

LANL. 2012. *Phase II investigation report for Sandia Canyon.* LA-UR-12-24593/EP2012-0195/ ERID-228624. September 2012. Available at <http://permalink.lanl.gov/object/tr?what=info:lanl-repo/eprr/ERID-228624>.

DRAFT

LANL. 2014a. *2013 Los Alamos National Laboratory annual site environmental report.* LA-UR-14-27564. September 2014. Available at <http://www.lanl.gov/community-environment/environmental-stewardship/environmental-report.php>.

LANL. 2014b. Chromium groundwater cleanup in Mortandad Canyon. Presentation by Danny Katzman to the Los Alamos County Board of Public Utilities. September 17, 2014. LA-UR-14-27217.

LANL. 2014c. Chromium groundwater cleanup in Mortandad Canyon. Presentation to the Northern New Mexico Citizens' Advisory Board. LA-UR-14-27280. September 24, 2014. Available at <http://www.nnmcab.energy.gov/7-presentations/Sep2014/NNMCAB_Chromium_Presentation_09-24-2014.pdf>.

LANL, 2015a. *Interim Measures Work Plan for Chromium Plume Control.* LA-UR-15-23126 / EP2015-0089. May 2015. Available at <http://permalink.lanl.gov/object/tr?what=info:lanl-repo/eprr/ESHID-600458>.

LANL, 2015b. *Work plan for chromium plume center characterization.* LA-UR-15-24861 / EP2015-0127. July 2015. Available at <http://permalink.lanl.gov/object/tr?what=info:lanl-repo/eprr/ESHID-600615>.

LANL. 2015c. *2014 Los Alamos National Laboratory annual site environmental report.* LA-UR-15-27513 / ESHID-600925. September 2015. Available at <http://permalink.lanl.gov/object/tr?what=info:lanl-repo/eprr/ESHID-600925-01>.

LANL. 2016. *2015 Los Alamos National Laboratory annual site environmental report.* LA-UR-16-26788. September 2016. Available at <http://www.lanl.gov/environment/assets/docs/reports/environmental-report/Current%20Report/2015-er-z.pdf>.

LANL and NMED. 2016. Intellus New Mexico environmental monitoring data provided by LANL and the NMED DOE Oversight Bureau. Available at <http://www.intellusnm.com/>.

McAda, D.P., and M. Wasiolek. 1988. *Simulation of the regional geohydrology of the Tesuque aquifer system near Santa Fe, New Mexico.* Water Resources Investigations Report 87-4056. United States Geological Survey, Reston, Virginia.

McCabe, G.J., M.A. Palecki, and J.L. Betancourt. 2004. Pacific and Atlantic Ocean influences on multidecadal drought frequency in the United States. *PNAS* 101(12): 4136-4141.

McLin, S.G. 2005. *Analyses of the PM-2 aquifer test using multiple observation wells.* Report LA-14225-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

McLin, S.G., W.D. Purtyman, A.K. Stoker, and M.N. Maes. 1996. *Water supply at Los Alamos during 1994.* Report LA-13057-PR, Los Alamos National Laboratory, Los Alamos, New Mexico.

Meyers, G. 2016. E-mail from Gaylyn Meyers, Los Alamos County Water Utility Engineering Project Manager, to Amy Ewing, Daniel B. Stephens & Associates, Inc. June 9, 2016.

National Oceanic and Atmospheric Administration (NOAA). 2013. *Regional climate trends and scenarios for the U.S. National Climate Assessment: Part 5. Climate of the Southwest U.S.* NOAA Technical Report NESDIS 142-5. January 2013. Available at <http://scenarios.globalchange.gov/sites/default/files/NOAA_NESDIS_Tech_Report_142-5-Climate_of_the_Southwest_U.S_0.pdf>.

NOAA Climate.gov. 2013. Historic rainfall and floods in Colorado. <http://www.climate.gov/news-features/event-tracker/historic-rainfall-and-floods-colorado>. September 17, 2013.

NOAA Climate.gov. 2014. Rising atmospheric moisture from global warming not to blame for 2013 Colorado flood. <http://www.climate.gov/news-features/event-tracker/rising-atmospheric-moisture-global-warming-not-blame-2013-colorado-flood>. October 2, 2014.

Newman, B.D., and B.A. Robinson. 2005. The hydrogeology of Los Alamos National Laboratory: Site history and overview of vadose zone and groundwater issues. *Vadose Zone Journal* 4(August 2005):614-619.

New Mexico Environment Department (NMED). 2012. LANL compliance order on consent. Revised April 2012. Available at <https://www.env.nm.gov/HWB/documents/LANL_Consent_Order_MODIFIED_4-20-2012.pdf>.

NMED. 2014. Risk assessment guidance for site investigations and remediation. December 2014. Available at <https://www.env.nm.gov/HWB/documents/RA_Guidance_for_SI_and_Remediation_12-24-2014.pdf>.

NMED. 2015a. Risk assessment guidance for site investigations and remediation. July 2015. Available at <https://www.env.nm.gov/HWB/documents/SSLs_RA_Guidance_for_SI_and_Remediation_July_2015.pdf>.

NMED. 2015b. Letter from John E. Kieling, Hazardous Waste Bureau Chief, to Doug Hintze, U.S. Department of Energy Los Alamos Field Office Manager, and Michael Brandt, Los Alamos National Laboratory Environment, Safety, Health Associate Director, regarding Approval with modifications, Work plan for chromium center characterization, Los Alamos National Laboratory. EPA ID#NM0890010515, HWB-LANL-15-036. October 15, 2015. Available at <http://permalink.lanl.gov/object/tr?what=info:lanl-repo/eprr/ESHID-600959>.

NMED. 2016. LANL compliance order on consent. Revised June 2016. Available at <https://www.env.nm.gov/HWB/lanlperm.html>.

New Mexico Office of the State Engineer (NMOSE). 2000. *Middle Rio Grande Administrative Area guidelines for review of water right applications.* September 13, 2000.

NMOSE. 2004a. *Active Water Resource Management priority basins.* October 28, 2004. Available at <http://www.ose.state.nm.us/water-info/misc-maps/AWRM-PriorityBasins.pdf> Accessed June 2005.

NMOSE. 2004b. Memorandum from D.L. Sanders, Chief Counsel, Susanne Hoffman-Dooley, AWRM Project Manager, and Martha Franks, AWRM Project Attorney, to File regarding Comments on the AWRM rules, and revisions made. December 3, 2004. Available at <http://www.ose.state.nm.us/doing-business/ActiveWaterMgt/FinalVersionAWRM-Comments.pdf> Accessed June 2005.

NMOSE. 2006. *Surface water transfer requirement to offset effects to the Rio Grande.* Water Rights Policy Division, January 10, 2006.

NMOSE. 2013. *New Mexico's water conservation planning guide for public water suppliers.* Technical report 53. Available at <http://www.ose.state.nm.us/WUC/PDF/Planning%20 Guide_Final_.pdf> Accessed December 2014.

NMOSE. 2016. Emergency authorization to use the ground waters of the State of New Mexico, File Number RG-00485 et al. September 10, 2016.

New Mexico Office of the State Engineer (NMOSE) / New Mexico Interstate Stream Commission (NMISC). 2006. *The impact of climate change on New Mexico's water supply and ability to manage water resources.* July 2006. Available at <http://www.nmdrought .state.nm.us/ClimateChangeImpact/completeREPORTfinal.pdf> Accessed May 9, 2014.

Overpeck, J., G. Garfin, A. Jardine, D.E. Busch, D. Cayan, M. Dettinger, E. Fleishman, A. Gershunov, G. MacDonald, K.T. Redmond, W.R. Travis, and B. Udall. 2013. Summary for decision makers. pp. 1–20 *In* Garfin, G., A. Jardine, R. Merideth, M. Black, and S. LeRoy (eds.), *Assessment of climate change in the southwest United States: A report prepared for the National Climate Assessment.* Island Press, Washington, DC. Available at <http://swcarr.arizona.edu/sites/default/files/ACCSWUS_Ch1.pdf>.

Poster Enterprises. 2014. Population projections developed for the State of New Mexico by Bruce Poster of Poster Enterprises.

Purtymun, W.D., and S. Johansen. 1974. General geohydrology of the Pajarito Plateau. p. 347-349 *In Guidebook to Ghost Ranch (central-northern New Mexico),* New Mexico Geological Society 25th Field Conference.

Rodriguez, C. 2016. E-mail from Cheryl Rodriguez, U.S. Department of Energy Environmental Management Program Manager, Los Alamos Field Office, to Gaylyn Meyers, Los Alamos County Water Utility Engineering Project Manager. August 24, 2016.

Rogers, D.B., A.K. Stoker, S.G. McLin, and B.N. Gallaher, 1996. Recharge to the Pajarito Plateau regional aquifer system. p. 407-412. *In* Goff, F. et al. (eds.), New Mexico Geological Society Guidebook, 47th Field Conference, Geology of the Los Alamos Jemez Mountains Region.

Southwest Water Consultants, Inc. (SWC). 1999. A*nalysis of return flow credits and water quality compatibility, County of Los Alamos.* May 1999.

Stewart, R. 2009. The ocean's influence on North American drought. *In Oceanography in the 21st century - An online textbook.* <http://oceanworld.tamu.edu/resources/oceanography-book/oceananddrought.html>.

U.S. Bureau of Reclamation (USBR). 2007. *Draft environmental assessment: San Juan-Chama water contract amendments with City of Santa Fe, County of Santa Fe, County of Los Alamos, Town of Taos, Village of Taos Ski Valley, Village of Los Lunas, and City of Española.* January 19, 2007. Available at <http://www.usbr.gov/uc/albuq/envdocs/ea/sanjuanchama/index.html>.

USBR. 2011. SECURE Water Act Section 9503(c) – Reclamation climate change and water 2011. Prepared for United States Congress. April 2011.

USBR. 2013. *USBOR west-wide climate risk assessment: Upper Rio Grande impact assessment.* Upper Colorado Region, Albuquerque Area Office. December 2013. Available at <http://www.usbr.gov/WaterSMART/wcra/docs/urgia/URGIAMainReport.pdf>.

U.S. Census Bureau. 1995. *New Mexico: Population of Counties by Decennial Census: 1900 to 1990.* Compiled and edited by Richard L. Forstall, Population Division, Washington, DC. March 27, 1995. <http://www.census.gov/population/cencounts/nm190090.txt> Accessed March 2006.

U.S. Census Bureau. 2006. *State and County QuickFacts: Los Alamos County.* January 12, 2006. <http://quickfacts.census.gov/qfd/states/35/35028.html> Accessed March 2006.

U.S. Census Bureau. 2010. *2010 Census summary file 1*. <http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml> Accessed January 2015.

U.S. Department of Commerce, National Bureau of Standards (U.S. Department of Commerce). 1959. *Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure.* Handbook 69. June 5, 1959. Available at <https://www.orau.org/ptp/Library/NBS/NBS%2069.pdf>.

U.S. Department of Energy (DOE) and Los Alamos County Water Utility (LACWU). 2016. Application for permit to change an existing water right (non 72-12-1) in support of the chromium plume control interim measure and chromium plume center characterization at Los Alamos National Laboratory. May 12, 2016.

U.S. Environmental Protection Agency (EPA). 2002. EPA facts about tritium. July 2002.

U.S. EPA. 2015a. Chromium in drinking water. Last updated November 23, 2015. Available at <https://www.epa.gov/dwstandardsregulations/chromium-drinking-water#is-total-chrome-health>.

U.S. EPA. 2015b. Summary table of derived concentrations (pCi/L) of beta and photon emitters in drinking water available at <https://www.epa.gov/sites/production/files/2015-09/documents/guide_radionuclides_table-betaphotonemitters.pdf>.

DRAFT

U.S. EPA. 2016. Regional screening levels (RSLs). May 2016 Available at <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016>.

U.S. Global Change Research Program (USGCRP). 2014. Extreme weather events of 2013: Human-caused or natural variability? <http://www.globalchange.gov/news/extreme-events-2013-human-caused-or-natural-variability>. October 10, 2014.

USGCRP. 2015. Southwest: Key messages about the Southwest from the National Climate Assessment. <http://www.globalchange.gov/explore/southwest>.

~~Vesselinov, V.V., D.R. Harp, R.J. Koch, K.H. Birdsell, and D. Katzman. 2008. *Estimation of aquifer properties based on pressure variations at monitoring wells caused by transient water-supply pumping.* LA-UR-08-0655. Available at <http://mads.lanl.gov/presentations/LA-UR-08-0655%20agu08%20hydro%20tomography%2020090203.pdf>.~~

~~Vesselinov. Velimir, D. Katzman, and D. Broxton. 2011. Buckman wellfield and its relation to groundwater beneath Los Alamos National Laboratory. *In* Simmons, A. (ed.), New Mexico Bureau of Geology and Mineral Resources Open File Report 536, *9th Annual Espanola Basin Workshop*.~~

Williams, A., P. Park, C.D. Allen, C. Millar, T. Swetnam, J. Michaelsen, C.J. Still, and S.W. Leavitt. 2010. Forest responses to increasing aridity and warmth in southwestern North America. *Proceedings of the National Academy of Sciences, USA* 107(50): 21289-21294.

Yanicak, S. 2016. E-mail from Steve Yanicak, New Mexico Environment Department DOE Oversight Bureau Los Alamos Oversight Section Staff Manager, to Gaylyn Meyers, Los Alamos County Water Utility Engineering Project Manager. June 21, 2016.

DRAFT