GEOARCHAEOLOGY OF THE WATER CANYON PALEOINDIAN SITE, WEST-CENTRAL NEW MEXICO

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Abstract

Water Canyon is a rare buried, multi-component, stratified Paleoindian site in west-central New Mexico. This paper presents a geoarchaeological assessment of the site as part of a broader interdisciplinary investigation of its paleoenvironmental history and archaeology. The archaeology is associated with ancient wetland deposits (Stratum 6) within an alluvial fan. The fan formed initially through the late Pleistocene. Formation of the fan stopped and wetland deposition began ~11,310 14C yr BP (~13,170 cal yr BP). Stratum 6 evolved via wetland deposition and cut-and-fill cycles. The bulk of Stratum 6 dates <10,300 14C yr BP (<12,200 cal yr BP). One, or possibly two, beds of bison bone, likely processing-stations, were found on the margin of the paleo-wetland and date to ~9200 14C yr BP (~10,400 cal yr BP) (lower bone bed) and ~8200 14C yr BP (~9150 cal yr BP) (upper bone bed). Farther out in the paleo-wetland a probable kill site was discovered with an in situ Eden projectile point dated to at least ~8955 14C yr BP.
yr BP (~10,070 cal yr BP). The wetland landscape returned to an alluvial fan system <8000 $^{14}$C yr BP (<8900 cal yr BP) with two more cycles of fan deposition by ~6500 cal yr.

Key Words: alluvial fan; paleo-wetland; bison kill; bison processing; Paleoindian; Eden point

1 INTRODUCTION

Paleoindian archaeological research in North America has been significantly influenced by work in the greater Southwest and neighboring areas. The Folsom type site, which resolved the debate over a late Pleistocene human presence in the Americas, is in northeast New Mexico (Figgins 1927; Meltzer 2006). The Clovis type site at Blackwater Draw, with a rich record of long-term Paleoindian occupation that established the classic Clovis-Folsom-unfluted artifact sequence, is in east-central New Mexico (Hester 1972; Howard 1933, 1935). In the heart of the Southwest, in situ, stratified Paleoindian sites are rare. Exceptions include the San Pedro River valley in southeastern Arizona, with at least four Clovis mammoth kills (e.g. Haynes and Huckell 2007), and in northern Sonora, Mexico, a Clovis-gomphothere kill and camp site is reported (Sanchez et al. 2014). To the north, in the San Luis Valley of Colorado, are Folsom age bison kill / campsites, such as Stewart’s Cattle Guard site (Jodry 1999).

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1 Geologically, the Basin and Range country west of the Pecos River Valley to the foot of the Sierra Nevada is one definition of the Southwest in the U.S. More informally, Reed (1964) offers a useful shorthand definition of the Southwest as extending from Durango, Colorado, to Durango, Mexico, and from Las Vegas, New Mexico, to Las Vegas, Nevada.
Paleoindian archaeology in the American Southwest is challenged by the rarity of terminal Pleistocene and early Holocene paleoenvironmental data from continuous stratigraphic sequences. Except for Clovis mammoth hunting, the chronologies for artifacts and occupations and the nature of subsistence activities must often be inferred from neighboring regions, usually the Great Plains to the east (e.g., Haynes 1975; Johnson 1987; Holliday 2000; Meltzer 2006; Haynes and Warnica 2012). The region’s paleovegetation and paleoclimate data tend to come from discontinuous records (e.g., packrat middens) and the sources of both types of paleoenvironmental data are widely scattered.

Here we report on the Water Canyon site in west-central New Mexico (Figure 1) (Dello-Russo et al. 2010). The site is unusual in the region, yielding evidence for multiple Paleoindian activity areas spanning the period from ~11,000 to ~8300 radiocarbon years before present (\(^{14}\)C yr BP) or ~13,000 to ~9200 calendar years before present (cal yr BP). Bone and stone artifacts, plant remains, and other classes of paleoenvironmental proxy data such as pollen, phytoliths, diatoms, stable carbon isotopes and land snails, were recovered from stratified, dateable deposits (Dello-Russo 2010, 2012, 2015; Dello-Russo et al. 2016a, 2016b). The \textit{in situ} Paleoindian components, buried in wetland deposits, are immediately adjacent to upland surfaces with additional evidence for Paleoindian activities. This paper focuses primarily on the stratigraphic and geochronologic record as they inform on the landscape evolution of the site and archaeological formation processes.
1.1 Site Location and Setting

The Water Canyon site is in west-central New Mexico on the southeast side of the La Jencia Basin just west of the Socorro Mountains and at the toe of an extensive bajada on the northeast side of the Magdalena Mountains (Figure 1). The site is along a tributary of the Water Canyon drainage which is, in turn, part of a tributary system of the Rio Grande (Machette 1988). The Water Canyon drainage heads on the northeast side of the Magdalena Mountains and flows east then north across a broad bajada (coalesced alluvial fans). Water Canyon joins South Canyon southeast of and upstream from the Water Canyon site. The combined drainage flows northeast and divides the Socorro Mountains and the Lemitar Mountains, at which point the drainage becomes Nogal Canyon and flows east to join the Rio Grande north of the city of Socorro. The mountains are composed of Oligocene volcanic rock. The volcanism and subsequent faulting, uplift of the mountains, and dropping of the basin are linked to the evolution of the Rio Grande Rift (Chapin et al. 2004; Hawley 2005).

The bajada with the Water Canyon site is known locally as the Water Canyon fan (Chamberlin and Osburn, 2006), but is referred to in this paper as the Water Canyon bajada. The site is currently dissected by three arroyos that formed in and emanate from a series of swales incised into the toe of this bajada (Figures 2, 3A, 3B). “No Name Arroyo”, formed in “No Name Swale”, is the middle of the three and cuts through the middle of the site exposing black paludal muds that led to the discovery of the Paleoindian-age bone and associated artifacts (Dello-Russo 2010). A smaller, unnamed arroyo occurs in the southeastern portion of the site.
The north side of the site is cut by “Big Wash.” Big Wash and No Name Arroyo converge in the eastern portion of the site. The combined drainages meet the unnamed arroyo at the far eastern edge of the site. From there the drainage flows east another 500 meters to join the main Water Canyon drainage. The site formed where the three aforementioned drainages emerge from narrow arroyos cut into the old bajada deposits.

2 FIELD AND ANALYTICAL METHODS

The geological and geoarchaeological investigations in and near the Water Canyon site included the recognition and mapping of landforms, and the examination, documentation, and dating of the stratigraphic record. All exposures and cores were measured and described using standard geologic and pedologic nomenclature and conventions (Table 1) (AGI 1982; Birkeland 1999; Holliday 2004). The site covers an area of over 9 hectares and is divided into seven “loci” (Figures 2, 3A). Stratigraphic exposures were available from archaeological hand-excavations in three loci (1, 3, and 5); six backhoe trenches (BHT-1, -2, -3 and -6 in Locus 1; BHT-4 in Locus 3; and BHT-5 in Locus 2), 75 cores (via Giddings coring rig), hand augers, and the three arroyos that cut across the site (Figures 2, 3A, 3B, S1). Numerous pollen and radiocarbon samples, together with a few bone samples, were recovered from these various exposures. A micromorphological study of sediments was carried out in Locus 1 (Supporting Information). Most of the archaeological excavations focused on Locus 1 North, along two sides of No Name Arroyo, and in a 12 x 12 m pit in Locus 5.
Assessing the chronology of the cultural deposits and the site stratigraphy was accomplished using radiocarbon and optically stimulated luminescence (OSL) dating techniques (Table 2). Radiocarbon ages were determined for soil organic matter (SOM) from buried soil horizons and organic-rich sediments, as well as for charcoal and bone collagen samples. The radiocarbon dating of organic-rich sediments can be somewhat problematic owing to the potential for contamination by younger humic acids (Martin and Johnson 1995; Abbot and Stafford 1996; McGeehin et al. 2001) but, with proper pretreatment, these materials can provide accurate, reproducible, stratigraphically consistent age control, especially in drier environments (e.g., Haas et al. 1986; Holliday et al. 1994, 1996; Quade et al. 1998; Rawling et al. 2003; Mayer and Mahan 2004). The Water Canyon SOM samples underwent a standard acid-base-acid treatment to remove carbonate and isolate specific fractions of organic matter (after Abbot and Stafford 1996). Radiocarbon ages were determined for the residue (NaOH insoluble) and humic acid (NaOH soluble) fractions using 1) the liquid scintillation method at the University of Arizona Isotope Geochemistry Laboratory (i.e., conventional radiocarbon; A-#s), and 2) accelerator mass spectrometry (AMS) at the NSF - Arizona AMS Laboratory (AA#s), the Beta Analytic, Inc. laboratory (Beta #s), Pennsylvania State University (PSU-#s), and the International Chemical Analysis laboratory (16OS/ and 16B/#s). Radiocarbon ages were corrected for isotopic fractionation and are presented as uncalibrated radiocarbon years before present ($^{14}$C yr BP) in the text and in Table 2. Calibrated ages and statistical means were determined using the CALIB 7.0.4 program (Stuiver and Reimer 1993) and the IntCal 13.14c
Dating by optically stimulated luminescence (OSL) was carried out on sediment samples by the University of Nebraska – Lincoln (UNL- #s; Goble 2014, 2015) and Utah State University (USU- #s; Rittenour 2011) (Tables 2, S1, S2). OSL ages are given simply as calendar years (yr) in the text. Calibrated radiocarbon years are considered to be equivalent to OSL calendar years.

3 RESULTS OF GEOLOGICAL STUDIES

The landforms and strata at the Water Canyon site can be grouped into two categories defined by age: those created during the older Pleistocene (defined here as Last Glacial Maximum [LGM] and older), including Strata 1, 2, 3, and 4; and landforms and more localized strata created in the terminal Pleistocene and early Holocene (TPEH) and later Holocene epochs (<18,000 yr), consisting of Strata 5, 6, 7 and 8, which are inset against the older strata.

3.1 Older Deposits and Landforms

3.1.1 Strata 1, 2, and 3

The topographic setting in the immediate area of the Water Canyon site is directly or indirectly related to geomorphic processes that created and modified the large, prominent Water Canyon bajada that characterizes the landscape of the southern La Jencia Basin (Figures 1, 3A). As noted, the arroyos that dissect the site are parts of drainages incised into the lower end, or toe, of the Water Canyon bajada. The uplands north of Big Wash and Locus 3, those
southwest of Locus 4, west of Locus 1, and the surface of Locus 6, represent the surface of the
toe of the Water Canyon bajada (Figure 4A). The bajada sediments (Stratum 1) consist of
“poorly to moderately sorted, bouldery to cobbly, volcanic-rich gravel, gravelly sand and
muddy silts. [They are] generally reddish orange to reddish brown, locally light brown to tan in
color
[and are] mostly non-indurated, however, the uppermost beds beneath its graded surfaces are
variably cemented by pedogenic carbonate horizons approximately 0.6 m to 0.1 m thick”
(Chamberlin 2005:6). The surface sediments have undergone some modification in the
immediate site area where they are characterized by carbonate-engulfed gravel. Less than a
kilometer to the west, the Water Canyon bajada surface is covered by sandy fines that display
an exceptionally well-developed soil (Bt horizon with red color almost 2.5YR, pervasive illuvial
clay, strong structure, and a Bk horizon with Stage III carbonate development). Because the
carbonate forms beneath the Bt horizon (Machette 1988), the areas of exposed carbonate on
the fan surface (e.g., the surface of Locus 6) are indicative of erosion of the less resistant Bt
horizon.

The age of the Water Canyon bajada is estimated at >500,000 to 25,000 years old based
on the degree of development of surface and buried soils nearby and radiometric age control
elsewhere (Machette 1988). Bajada construction probably ended when drainages in the La
Jencia Basin integrated with the Rio Grande through Nogal Canyon (Machette 1988:5).
A younger bajada-related surface was identified at Locus 2, lower in elevation than the broader
bajada surfaces to the north, west and south (Figures 2, 3A). The archaeological
materials at Locus 2 are emplaced on this younger surface which is expressed as a narrow, flat
ridge roughly two to three meters below the local bajada surface. This surface was created
when the upper portions of the older bajada deposits were eroded. The sediments underlying
this ridge represent an early episode of filling (Stratum 2) following incision of the bajada
surface sometime before 42,000 years ago (Figure 4B; see OSL discussion below). Backhoe
trench 5 (BHT-5; Figure 2B) exposed a paleochannel in the Stratum 2 fill below this surface
(Figure 4C). Designated as Stratum 3, the fill in this paleochannel includes sandy, loamy and
slightly gravelly alluvium inset into the older, coarse, well-sorted and well-rounded gravel of
Stratum 2. Minimal soil development on this surface suggests that Locus 2 has been
undergoing continued erosion.

Two OSL ages on the sand indicate that both strata below the Locus 2 surface are pre-
LGM in age. The age of Stratum 2 alluvium ranges between ~32,000 and 41,000 yr and the age
of the inset Stratum 3 sediment is between ~29,100 and 37,500 yr (Table 2). The ages appear
to be reasonable given the estimated age of the stratigraphically older bajada surface (Middle
Pleistocene) and the dating of the younger terminal Pleistocene fill (discussed below).

3.1.2 Stratum 4

Stratum 4 is topographically lower than Strata 1, 2, and 3, inset against the eroded toe
of the bajada (Figures 4E). It consists of sandy and pebbly alluvium with more local clayey
facies. A strongly developed soil (Bt horizon with 7.5YR hues and thick, continuous clay films,
and pervasive carbonate coatings on ped faces) formed through most of the stratum. Stratum 4 is most obvious on the south side of the site. It is found along the southwest margin of Locus 1 (Locus 1 South), at the foot of the scarp that leads up to the old bajada surface, exposed in BHT-6 (Figure 5) and in cores through the area (Figure S1). It is inferred to be present to the south in Locus 4 based on an exposure in the unnamed arroyo that separates Locus 1 from Locus 4.

In Locus 1 South the top of Stratum 4 forms a bench, likely an alluvial terrace, almost imperceptible topographically (Figure 5). This bench was initially recognized because of the dense concentration of coarse gravel at the surface along with a high concentration of lithic artifacts, including conjoining fragments of a probable Paleoindian projectile point and related artifacts. The layer of gravel with the artifacts rests on Stratum 4 and its associated soil.

The dating of Strata 2 and 3 suggests that Stratum 4 is <30k years old, assuming that the OSL dating in Locus 2 is accurate. Unweathered alluvium at the base of Stratum 4 (below the Stratum 4 soil) in BHT-6 yielded an OSL date of ~18,000 yr (Table 2). This date could be accurate or it is a minimum age. The degree of development of the soil formed in Stratum 4 suggests that the surface stabilized and then underwent pedogenesis for at least a few tens of thousands of years, based on dating of soils in similar settings across the Southwestern U.S. (Gile et al. 1981; Machette 1988; Birkeland 1999; Holliday 2004). Stratum 4 is also present near the north end of the site in Locus 3 and was exposed in BHT-4. At the base of the sequence in BHT-4 is a reddish sandy layer that yielded another OSL date of ~18,000 yr (Table 2). Soil development in this deposit and the OSL dating at the base of the deposit indicate that this layer is equivalent
to Stratum 4 in Locus 1 South. These dates suggest that there must have been an additional
phase of local (if not regional) deep incision between ~30,800 and ~18,000 yr.

The gravel layer on the bench in Locus 1 South and resting on the Stratum 4 soil may be
entirely redepoted from the adjacent scarp and bajada surface, but more likely the gravel was
in place on the bench. The artifacts on that bench probably represent in situ occupation
because the archaeological debris is continuous from Locus 1 South to and across Locus 1
North. Artifacts within the gravel may have been mixed in via bioturbation and soil shrink-swell.

### 3.2 Terminal Pleistocene and Holocene Deposits

The TPEH deposits at the Water Canyon site are the focus of our research. They contain
the *in situ* archaeological record at the site. The deposits are divided into five stratigraphic
units: four lithostratigraphic units (5, 6, 7, and 8) and one soil-stratigraphic unit (the La Jencia
Soil). Facies of the strata are defined on the basis of lithological characteristics or color or both.
Color variation includes post-depositional alteration, primarily by groundwater modification.

#### 3.2.1 Stratum 5

Stratum 5 is a pebbly to gravelly to cobbly and locally sandy deposit that underlies
Stratum 6 throughout much of the site. Data from Locus 1 suggest that Stratum 5 deposits are
inset against Stratum 4 in a channel cut below Stratum 4 (Figure 4G). Exposures of Stratum 5
were limited to Unit 1-6 in Locus 1 and adjacent No Name Arroyo walls (Figure 3B), and in Unit
5-1 of the Locus 5 excavation block (Figure 6B). The coring rig rarely penetrated deeply into the gravel and, therefore, we could not determine the thickness of the deposit in most cores nor the character of it or its underlying deposits.

Stratum 5 is complex topographically, stratigraphically, and geochronologically. For example, where initially observed along No Name Arroyo (Units 1-6 and 1-5 in Locus 1 North), the top of Stratum 5 gravel is at 47.00 m and 47.03 m grid elevation, respectively. But 10 meters to the northeast, in the southwest corner of the deep Locus 5 excavation block (Unit 5-1), the top of the gravel is at 45.39 m grid elevation (Figures 6B, 7). Similarly, running from Locus 1 North to the east-southeast (based on coring) elevations for the contact between the top of Stratum 5 and the base of overlying Stratum 6 show a dramatic change in elevation of almost 4 meters (Figure 8). The mud of Stratum 6 engulfs the Stratum 5 gravel in some areas of the site (Locus 1: Cores 9-2, -6, -7, -10, -15, -18; Locus 3: Cores 10-15, -17; Locus 5: southwest corner of main pit and Core 10-10). In contrast, in BHT-4, cut across Locus 3, a time-stratigraphic valley-margin equivalent is composed of gravelly sand that is likely from slope wash based on thickening and facies changes toward the old bajada uplands (Figure 9).

The age and sequence of Stratum 5 deposition is difficult to interpret, limiting our understanding of the site formation processes. The estimated age range of the deposit can only be based on dates from above and below. As noted previously, the two OSL ages from the older (pre-TPEH) Stratum 4 deposits in Locus 1 (BHT-6; Figure 5; UNL-3856) and Locus 3 (BHT-4; Figure 9; UNL-3859) provide an approximate minimum age for the base of Stratum 5 at ~18,000
yr (Table 2). The oldest radiocarbon age for overlying Stratum 6 is ~11,310 $^{14}$C yr BP (~13,170 cal yr BP).

As a whole, the paleo-topographic expression of Stratum 5 is that of an alluvial fan (Figure 4G). Elevations on top of Stratum 5 in and near Locus 1 and Locus 5 show that, at the mouth of the No Name Swale, Stratum 5 slopes down by several meters to the northeast across Locus 5 and to the southeast away from Locus 1; i.e., it has the shape of a fan with apex at the mouth of No Name Swale. The layer varies in content of sand, pebbles, and gravel, and degree of sorting from exposure to exposure. Alluvial fans are characterized by cut-and-fill cycles and that could account for the dramatic variability in lithology. Big Swale has a larger drainage area than No Name and likely contributed to deposition and erosion of Stratum 5. But very little of our stratigraphic or geochronological data can be directly linked to alluvial processes in Big Wash because very little late Quaternary fill is preserved there.

3.2.2 Stratum 6

Stratum 6 contains most of the archaeological remains recovered in situ at the Water Canyon site, primarily in Locus 1 North and Locus 5. It is up to ~200 cm thick and is primarily a dark gray to black mud, but there are several facies. Lighter gray and olive green facies are locally common as is an upland soil facies. In some areas of the site the mud encases underlying gravel, producing a mix (vertical facies) of Strata 5 and 6. Along the margins of the site there is also an upland soil facies. Stratum 6 in at least one of its facies was found everywhere across
the site except at the far east central portion of the site, east of Locus 1 and north of Locus 4 (Cores 10-23 to 29), due to erosion. One of the thickest and most complete sections of Stratum 6 is located in and just east of Locus 5. Stratum 6 rests unconformably on Stratum 5 and is locally inset against it or Stratum 4. Along No Name Arroyo and south across Locus 1, Stratum 6 is both atop and inset into Strata 4 and 5 (Figures 3B, 5, 7).

The dark gray-to-black mud facies of Stratum 6 with its distinctive color and presence of bone, is the most ubiquitous stratigraphic marker at the site (Figure 10). The dark color, fine-grained lithology, based on field texture and micromorphology (below and Supporting Information), and dating suggest slow aggradation of fines under conditions of high biological activity. The dark, subdued coloration and apparent biological activity tends to inhibit evidence for physical weathering such as root casts or cracking.

The olive green facies is a local biochemical alteration of Stratum 6. Where observed, the olive green facies is always below the black/dark gray facies and just above the gravel of Stratum 5 (Figure 10). The colors (gleyed or low chroma) are typical of reducing conditions in the presence of a high water table and abundant organic matter (Schaetzl and Thompson 2015: 483). The absence of mottled redoximorphic features (i.e., colors of both reduced and oxidized iron) are indicative of year-round saturation rather than seasonal water table fluctuation (Schaetzl and Thompson 2015: 356-358, 484). The gleyed facies is common only in the area of Locus 1 and to the southeast of Locus 1, but also minimally present far to the northeast along Big Wash (section 12-9) and in an abandoned pit by an old windmill (Windmill Pit, Figure 2A).
This patterning puts the gleyed facies in proximity to the older pre-TPH gravels and the bajada gravels, which, along with flow down the local drainages, could have been a source of seep or spring water that kept Stratum 6 saturated along the site margins.

The micromorphological analyses of thin sections collected in the Locus 1 excavation block provide some clues to the origin of Stratum 6 (Supporting Information). The thin sections (Figures S4-S11) show that there are subtle differences in the lithology of Stratum 6 in Locus 1, thus we subdivide it in Locality 1 into 6A and 6B. The lower part of the layer (6A) is finer (silt and clay), weakly laminated and pervasively gleyed. This suggests very low energy alluvial aggradation and perhaps additions of dust followed by reduction. Upper Stratum 6 (6B) is likewise dominated by fines and exhibits some weak bedding, but it contains some fine to medium gravel. The coarser particles are sub-rounded to angular, suggestive of short-distance transport.

Stratum 6B is mostly dark gray to black, but the micromorphology shows that the gleying characteristic of 6A also crossed the boundary between 6A and 6B and modified the lowermost portion of Stratum 6B. This discovery highlights the importance of differentiating facies based on sedimentological characteristics from those based on post-depositional characteristics. Stratum 6B exhibits localized gleying and some redoximorphic features, indicative of short-term saturation. The incomplete gleying and persistence of darker coloration is suggestive of either high original organic matter content or rapid burial shortly after deposition of 6B. However, development of soil structure and coatings of illuvial clay in 6B
demonstrate a period of subaerial weathering of 6B prior to burial. All thin sections also
provide evidence of syndepositional or post-depositional bioturbation.

The gray facies is a deposit locally above and disconformably on the black/dark gray
facies. It is common in the east-central area of the site, in and around Locus 5. The gray facies
of Stratum 6 are sandy and locally pebbly near the site margins, probably picking up coarser
clastics as slope wash. The upper gray mud also tends to be generally sandier. Influxes of sand
(probably by both eolian and slope wash processes) would dilute the organic matter content
and make the color lighter. The presence of oxidized iron staining (redoximorphic features) in
the exposures of upper gray muds upstream of Locus 1 in the No Name Arroyo cut banks
suggests the occurrence of seasonal water table fluctuations during the early Holocene.

A well-drained upland soil facies of Stratum 6 is located on topographically slightly
higher settings in the north-central portion of the site (along the northeast edge of Locus 3)
and on the bench along the southeast margin of Locus 1 South (Figures 9 and 5, respectively).
This upland facies is a dark gray to black soil A-horizon. The sub-horizons of this soil (formed in
Stratum 4; discussed above) vary from Bk horizons in sand to a clayey, well developed Bt
horizon (Table 1; Figures 5 and 9). The topographic and stratigraphic facies relationships
between the black mud facies and the soil facies show well at the south end of BHT-6 in Locus
1 where the soil is formed on two levels of the bench (Figure 5). Soil formation was on stable,
slightly elevated landscapes roughly contemporaneous with aggradation of the other facies in
lower settings.
Stratum 6 apparently was subjected to several phases of erosion. This interpretation is based on the variable thickness of the layer, the abrupt and locally irregular contacts between Stratum 6 and overlying Stratum 7, the local presence of gravel lenses within Stratum 6 and on the Strata 6/7 contact, and radiocarbon dating. Otherwise, erosional contacts within Stratum 6 are difficult to identify due to the uniformly dark coloration which, as noted, obscures contacts such as erosional surfaces. In the exposure along the north side of No Name Arroyo, in the area of Locus 1 North and in the Locus 5 deep excavation block, at least one disconformity was observed within the gray facies of Stratum 6. More prominent is a disconformity at the top of Stratum 6 in Loci 1 and 5 and a disconformity cross-cutting Stratum 6 in the south and west walls of Locus 5. The latter erosion is due to the action of a re-routed paleo-arroyo (an earlier version of No Name Arroyo, discussed more fully below) that cut down through Stratum 6 and subsequently filled with Stratum 8.

The radiocarbon age estimates for the base of the Stratum 6 muds, either resting on top of the Stratum 5 gravel or encasing it, tend to be in the range of ~10,000 to ~9500 $^{14}$C yr BP ($\sim$11,450 to $\sim$10,800 cal yr BP) across much of the site (Table 2). There are several significant exceptions to this trend, however. In Locus 1, on top of the Stratum 5 fan, the base of Stratum 6 yielded dates of 11,310 and 11,030 $^{14}$C yr BP ($\sim$13,170 and $\sim$12,895 cal yr BP). Just northeast in the Locus 5 excavation block, lower Stratum 6 is dated 10,280 to 10,000 $^{14}$C yr BP ($\sim$12,005 and $\sim$11,450 cal yr BP). Along the northeast margin of the site in or near Big Wash the base of Stratum 6 dates to $\sim$8810 $^{14}$C yr BP ($\sim$9820 cal yr BP). Further, dating and distribution of bone
and lithic artifacts in Locus 1 North suggest an unconformity in the range of \(~9200 \text{ to } \sim8300\) \(^{14}\text{C}\) yr BP (\sim10,390 \text{ to } \sim9100\) cal yr BP) (Figure 11). All of these ranges in radiocarbon ages suggest several episodes of significant erosion and incision. The earliest phase of erosion isolated, and left in place, a small pocket of Clovis-age muds in Locus 1 just beyond the mouth of No Name Swale and on top of the Stratum 5 fan. This erosion may have been between \sim11,000\) and \sim10,360\) \(^{14}\text{C}\) yr BP (\sim12,890 \text{ and } \sim12,240\) cal yr BP) given the absence of dates in this age span across the remainder of site. Another cycle of erosion apparently was relatively widespread, given the extent of basal dates in the range of \sim10,000 \text{ to } \sim9500\) \(^{14}\text{C}\) yr BP (\sim11,450 \text{ to } \sim10,800\) cal yr BP) across the site. The degree of erosion is highlighted by the topographically lowest component of Stratum 6 in Core 10-26, downstream (\sim130\) meters) far to the east of Locus 1 and at grid elevation 41.8 m (compared to 47.0 m in Locus 1 and 46.2 m in core 9-10) (Figure 8). The base of Stratum 6 in that core dates to \sim9745\) \(^{14}\text{C}\) yr BP (\sim11,170\) cal yr BP).

Sedimentation resumed, and then another phase of erosion ensued along Big Wash >8810 \(^{14}\text{C}\) yr BP (\sim9820\) cal yr BP) and then along paleo-No Name Arroyo >8300 \(^{14}\text{C}\) yr BP (>9100\) cal yr BP).

In Locus 5, the Stratum 6 black facies began to develop by \sim10,280 \(^{14}\text{C}\) yr BP (\sim12,005\) cal yr BP), which is older than some of the dating of the gleyed facies in Locus 1. The gleyed facies of Stratum 6 in Locus 1 and elsewhere in the site likely started as the black facies (the presence of abundant organic matter would help drive the gleying, as noted above). The process of gleying, therefore may have begun after \sim10,280 \(^{14}\text{C}\) yr BP, but it is not isochronous across the site. The gleyed facies at the base of Stratum 6 in Section 12-9 along Big Wash is dated to \sim8810.
The age of the upland soil facies of Stratum 6 is, in part, a function of localized upland

$^{14}$C yr BP (~9820 cal yr BP), but the gleying could post-date the carbon that was dated.

The transition of the black facies to the gray facies is not well dated, but numerical age

estimates in Loci 1 and 5, and in Core 10-7 (Figures 2A, S1; Table 2), provide some clues. In

Locus 1, Unit 1-9, the upper black facies is dated to ~9310 $^{14}$C yr BP (~10,535 cal yr BP). A

concentration of charcoal fragments in the upper part of the gray facies, interpreted as hearth

Feature 1 (Unit 1-11), produced a mean date of ~8321 $^{14}$C yr BP (~9365 cal yr BP). In Locus 5,

charcoal from the upper black facies dated ~8775 $^{14}$C yr BP (~9755 cal yr BP) and charcoal from

the gray facies dated ~8395 $^{14}$C yr BP (~9400 cal yr BP). Similarly, just east of Locus 5 in Core

10-7, the transition occurred between ~8630 $^{14}$C yr BP (black facies) (~9660 cal yr BP) and

~8305 $^{14}$C yr BP (gray facies) (~9280 cal yr BP).

This transition from black to gray is usually indicated by an abrupt contact and locally

accompanied by gravel, thus denoting some erosion. This likely explains some of the variable

dating among the three areas of the site. Erosion across the top of the black facies clearly

provides some variability. The timing of the black-to-gray transition could also be locally

variable across the site depending on influx of coarse clastics. The much younger ages for the

two facies on Core 10-7 may also be due to unknown contaminants.

The upper gray facies of Stratum 6 yielded broadly similar dates in Loci 1 and 5 and in

Core 10-7: ~8395 $^{14}$C yr BP (~9400 cal yr BP) in Locus 5; ~8321 $^{14}$C yr BP (~9365 cal yr BP) in

Locus 1; and ~8050 $^{14}$C yr BP (~8940 cal yr BP) in Core 10-7.

The age of the upland soil facies of Stratum 6 is, in part, a function of localized upland
geomorphic processes. On the northeast side of Big Wash, in the Windmill Pit (Figure 2A), the upland soil facies yielded two dates of ~5600 $^{14}$C yr BP (~6385 cal yr BP) (upper) and ~6500 $^{14}$C yr BP (~7395 cal yr BP) (lower). Downstream from the Windmill Pit, approximately 320 meters along Big Wash (section 15-20, a black mud facies produced a date of ~6125 $^{14}$C yr BP (~7050 yr BP). This could indicate that the black, upland soil on the north side of Locus 3 is a facies of a younger version of the Stratum 6 black muds. Deposition of Stratum 6 spanned ~11,310 to ~8000 $^{14}$C yr BP (~13,170 to ~8900 cal yr BP). Breaks in the geochronology are indicative of erosion, in particular between ~11,030 and ~10,360 $^{14}$C yr BP (~12,895 and ~12,240 cal yr BP) and between ~9900 to ~9500 $^{14}$C yr BP (~11,310 and ~10,800 cal yr BP). These breaks and even erosion could also be due to drying conditions that precluded formation of a wetland.

3.2.3 Strata 7 and 8

Strata 7 and 8 are discussed together because of their similar lithologies and depositional environments. They are distinct stratigraphic entities, however. This inference is based on the presence of a mappable erosional disconformity between the two (Figure 6A). Both layers are sandy and gravelly, but fines are more common than in Strata 4 or 5 (Table 1). The exposures in the excavation block in Locus 5 show that Stratum 7 was deposited on top of the Stratum 6 gray facies following a phase of east-dipping erosion and gravel deposition across Stratum 6 (Figure 6A). A moderately well-developed soil formed in upper Stratum 7 where it is unburied and in upper Stratum 8. The soil varies in thickness from 30 to >100 cm, depending on
the thickness of the parent material (i.e., the thickness of Stratum 8 or unburied Stratum 7). It is usually a red Bt horizon that forms a distinct soil stratigraphic unit, here referred to as the La Jencia Soil. The degree of development of this soil was one of the stratigraphic characteristics that led to the realization that the black muds (Stratum 6) underlying Stratum 7 are of some antiquity.

The thickness of the combined Strata 7 and 8 decreases to the northeast, east, and southeast away and downstream from both Locus 1 and the mouth of No Name Arroyo (Figures 4I, 7). Similarly, the surface of these deposits (i.e., the present-day surface of the Water Canyon site) slopes down in the same directions, following the topography trending downslope with the present-day No Name Arroyo. These characteristics, together with the coarse nature of the sediments and the cut-and-fill stratigraphy, provide further indications that these strata comprise the upper portions of an alluvial fan at the mouth of No Name Swale.

Some cores revealed evidence of a buried soil (in the form of a Bw horizon or weakly expressed Bt horizon) in alluvium resting on Stratum 6 and, in turn, buried by younger alluvium, although this buried soil is not continuous across the site. In Locus 3 and Locus 1 South, the upland facies of Stratum 6 is locally, but not completely, buried by a layer of cobbles or by finer sediments with an A-Bt soil. The relative ubiquity and similar morphology of this covering soil, distributed discontinuously across the site, suggests that it is the same soil in each instance. As such, the alluvium in Loci 3 and 1 South most likely represents an eroded remnant of early Strata 7/8. Further, the presence of at least one buried soil shows that Strata 7/8 aggraded
An ancient channel of No Name Arroyo (referred to in this paper as paleo-No Name Arroyo) cut across the middle of the Water Canyon site, down through Stratum 7 and deep into Stratum 6. It was subsequently filled with Stratum 8. This paleo-arroyo was exposed in the southwest corner of the Locus 5 excavation block (Figures 6A, 6B) and can be traced upstream to the north wall of the present-day No Name Arroyo. The north wall of the paleo-arroyo was relatively steep (i.e., as exposed on the Locus 5 block) as was the lower half of the south wall of the paleo-arroyo as exposed in the modern No Name arroyo. But on the south side of the modern arroyo and in BHT-3, erosion by the upper half of the paleo-arroyo was more nearly horizontal, cutting across the top of the Stratum 6 black facies. Where it fills the paleo-arroyo, and prior to subsequent erosion, Stratum 8 is >3 m thick. Deposition of Stratum 8 was in at least two cycles, as indicated in the Locus 5 exposure (Figure 6A). The upper deposit of Stratum 8 thins to the south and is ~1 m thick as exposed in No Name Arroyo in Locus 1 (Figure 3B) and thins to less than 1 m further to the south (Figure 5).

There are no reliable dates directly from Stratum 7 in the areas of Locus 1 or Locus 5. It is younger than the Stratum 6 gray facies (<8050 $^{14}$C yr BP; ~8940 cal yr BP) and older than Stratum 8, which is inset against it. The sheet of alluvium across the surface of Locus 3 produced an OSL age of ~8070 yr (Figure 9), further suggesting that it is a facies of Stratum 7. Stratum 8 produced a wide range of OSL dates and no radiocarbon dates. The OSL age estimates range from ~9210 to ~8540 to ~6560 yr among the five dates from Locus 5 and one
date of ~9770 yr from BHT-3 in Locus 1 (Table 2). The sequence from Locus 5 comes from the fill in the paleo-arroyo (precursor to No Name Arroyo) and also contains several reversals. Given the upper radiocarbon age of <8050 $^{14}$C yr BP from upper Stratum 6, the three OSL dates in the range of ~9770 to ~9020 yr (with large standard deviations) likely do not date the deposition of Stratum 8. Given the short transport distances of sediments in the fan and potential problems of OSL dating of alluvium (Walker 2005: 99; Bradley 2015: 97), partial bleaching is a likely problem. The same problem could also apply to the date of ~8540 yr (R. Goble, personal communication, Feb. 3, 2017). The two youngest OSL dates from the sequence, ~6480 yr from the lower paleo-arroyo fill, and ~6560 yr from the top of Stratum 8, appear to provide the best age estimates and suggest no significant break in time between deposition of lower and upper Stratum 8.

4 ARCHAEOLOGICAL SUMMARY

After the site’s initial discovery, The Water Canyon site has been subjected to both archaeological survey and excavation. The artifact assemblages in surface contexts at Loci 1, 2, 3, 4, and 6 were mapped and analyzed in the field. These assemblages included hundreds of core flakes, biface thinning flakes, other debitage, projectile points, and tools. Fourteen diagnostic projectile points and point fragments were collected from the surface and one diagnostic projectile point was recovered from an in situ buried provenience (Table 3).

The faunal assemblage retrieved thus far from Locus 1 consists primarily of ~177 Bison...
sp. bone elements and bone fragments (of which 60 are identifiable to element), and tooth enamel pieces representing at least one bull, one to two cows, and three juveniles (Akins 2012; Dello-Russo et al. 2017). The horizontal extent of the Locus 1 faunal deposit is currently not completely defined and, although it may continue a little further to the east, no faunal remains were encountered in BHT-3, so it is likely that the majority of the assemblage has been recovered. Collagen samples from six elements have been radiocarbon dated and have returned ages ranging from \(~9240\) to \(~8200\) \(^{14}\)C yr BP (\(~10,390\) to \(~9150\) cal yr BP) (Figure 11; Table 2), suggesting that the bone bed might represent the remains of at least two, and possibly three, chronologically separate events (Dello-Russo et al. in press).

Given these possibilities, a further exploration of the chronometrics in Locus 1 N is warranted. Three of the bone collagen radiocarbon dates from Locus 1 N (\(~9180\) \(^{14}\)C yr BP, PSU-3564; \(~9240\), PSU-3565; \(~9185\); PSU-3566; Table 2) are from the lower bone cluster and they are statistically the same (Figure 11). These three collagen samples were subjected to ultra-filtration during pretreatment and their C/N ratios were each 2.8, indicating that the collagen in each sample was of sufficient quality to provide a reliable date. Their mean radiocarbon date (\(~9204\) \(^{14}\)C yr BP \(\pm 30\)) is statistically different than that of the dated collagen sample in the upper portion of the bone bed (\(~8200\), Beta 292053) (Figure 11). This suggests that the upper portion of the bone bed represents a later depositional event than the lower portion of the bone bed. It also suggests that the upper bone bed is similar, although statistically different, in age to the Feature 1 hearth at a mean date of \(~8321\) (Figure 11). No C/N value is available for
this upper bone collagen date, nor was the sample subjected to ultra-filtration during pretreatment, so it is likely that the date for this collagen sample is a little too young.

In addition, there are two other bone collagen dates in Locus 1 N (~8810, PSU-3567; ~8640, 16B/0713; Table 2) which, being only slightly different themselves (t=4.446), suggest a third possible bone cluster whose mean radiocarbon age (8682 ±35) is statistically different in age than both the lower bone bed and the upper bone bed (Figure 11). The collagen sample for the ~8810 date was subjected to ultra-filtration during pretreatment, while the collagen sample for the ~8640 date was not, so the latter date is probably a little too young. The three groupings of bone, artifacts, and charcoal illustrated in a back plot (Figure 11) present hypothesized temporal relationships of cultural materials and highlight the location of 1) the disconformities that we infer to exist between the upper and lower Bison sp. bone beds in Stratum 6 and 2) a possible disconformity between the western Bison sp. bone bed and the eastern Bison sp. bone cluster. Given the known potential for erosional unconformities in Locus 1 N, therefore, these dates and artifact groupings may reflect the processes involved in creating the cultural deposit.

Feature 1 in Locus 1 North (Figure 11) produced a dense concentration of charcoal fragments. Ten were identified as oak, pine, Ponderosa pine, juniper, and an unknown hardwood species (McBride 2012; Davis 2012). These 10 samples returned radiocarbon ages that are statistically similar (t=5.079) with a pooled mean ranging from ~8307 to ~8339 14C yr BP (~9113 to ~9525 cal yr BP). Only two of the charcoal dates fall within the range of ages provided by the dated bone (~8160 to ~8240 14C yr BP) in the upper portion of the bone bed.
These charcoal fragments were also directly associated with burned and calcined bone fragments, and carbonized amaranth and goosefoot seeds. From these data, we infer the past presence of a small thermal feature or hearth (Buenger 2003; c.f. Surovell et al. 2016:83) spatially associated with the uppermost portion of the Locus 1 bone bed.

The lithic artifact assemblage recovered from Locus 1 North includes 141 unutilizeddebitage flakes, three retouched or utilized flakes, four bifaces, and four multipurpose tools, five scrapers, and two projectile point or hafted knife fragments, as well as a small, slab grinding / anvil implement. The types of artifacts in the assemblage, together with hearth charcoal, burned/calcined bone and a number of long bones that exhibited percussion marks, bone flakes and green-bone fracture edges comprise what we infer to be the remains of one, and possibly two, open-air activity areas utilized for bison processing during the Late Paleoindian (Allen-Frederick?) and the Cody (Eden) periods (Dello-Russo et al. in press). The affiliation of the upper open-air activity area with a possible Allen-Frederick occupation and the lower activity area with a possible Cody (Eden) era occupation are based on the probable dates of the bone beds themselves, at ~8200 $^{14}$C yr BP and ~9200 $^{14}$C yr BP, respectively. No temporally diagnostic artifacts were found in direct association with either of the bone beds. The Locus 1 N Allen-Frederick era date conforms well with the 9350-7900 $^{14}$C yr BP range suggested by Pitblado (2003:112) for Allen-Frederick in the southern Rocky Mountains and the Locus 1 N Cody (Eden) date conforms well with the ~9800-8800 $^{14}$C yr BP range suggested by Knell and Muñiz (2013:11) for Eden on the High Plains.
An additional *Bison sp.* bone bed was discovered by mechanical coring in Locus 5, at approximately 3.5 m below the present-day ground surface in the black facies of Stratum 6. Directly associated with this deposit and recovered *in situ* in hand-excavated Unit 5-1, was the resharpened Eden projectile point. This is the only diagnostic artifact recovered from Locus 5, to date. Only 10 other lithic artifacts have been recovered from Stratum 6 in Locus 5 so far. We have also recovered, to date, more than 91 faunal elements, fragments, and tooth enamel pieces from the Locus 5 *Bison sp.* bone bed. These faunal elements recovered from Locus 5 represent an unknown number of individuals and their analyses are continuing. The bone bed is thought to cover more than 50 square meters and hand excavations in this area, thus far have only opened 10 one-by-one m units.

Determining the age of the *Bison sp.* bone bed and the associated Eden point in Locus 5 has proven problematic. Samples of bison bone and teeth yielded no collagen, thus far precluding the possibility of direct dating. When the feature was first encountered in core 10-1, Stratum 6 encased the bone. Two samples were collected and the SOM was dated (Figure 12; Table 2). The samples produced two dates between ~9887 and 9640 $^{14}$C yr BP (~11,305 and ~10,975 cal yr BP), from below and above the bone, respectively. These dates are stratigraphically correct and statistically different and could, thus, be accurate. Accordingly, the age of the encased bone could be the mean of these two dates, or ~9718 $^{14}$C yr BP. However, the difference in the dating could also be in part a matter of inter-laboratory variation (Taylor and Bar-Yosef 2014:147). Elsewhere in Locus 5, a similar SOM date of ~9750 $^{14}$C yr BP (~11,180...
cal yr BP) from a sample taken just below the bone bed in Unit 5-1 provided confirming
evidence that the bone bed was no older than this and in the range of ~9718 to ~9750 $^{14}$C yr
BP. This falls at the older end of the age range for Eden points as currently known for western
North America (Knell and Muñiz, 2013:11-12).

Alternatively, the Locus 5 bone bed age might be indicated by an SOM date of ~8955 $^{14}$C
yr BP (~10,070 cal yr BP) determined on a sample collected near the Eden point found in the
uppermost portion of the bone bed (Table 1) (Dello-Russo et al. in press). This date is well
within the age range for Eden points on the northern and central Great Plains (Knell and Muñiz
2013:11-12) and within the range for Firstview points on the southern Great Plains (Holliday
2000). This leaves two scenarios for the age of the bone bed: the older dates could be due to
mixing (from bison and human trampling during the kill and initial butchering and/or via
bioturbation as the paleo-wetland evolved) or Eden occupations may be older in the Southwest
than on the Great Plains.

5 DISCUSSION and CONCLUSIONS

The Water Canyon site is notable in the Southwest for its multiple Paleoindian
occupations in an intact, stratified context (the only such documented Paleoindian site in New
Mexico west of the Pecos River), its multiple Bison sp. bone beds, and its extensive paleo-
wetland with abundant paleoclimatic and paleoenvironmental proxy data. The Water Canyon
site is also unusual in being one of the few Paleoindian sites preserved in an alluvial fan. The
site formed at the mouths of several swales cut into the distal toe of the old bajada flanking the Magdalena Mountains and emptying into the Water Canyon drainage (Figure 4). Archaeological materials are found at the surface on older, stable coalesced fan surfaces and on stable surfaces formed on Late Pleistocene sediments inset against those older fan surfaces. Buried, in situ cultural deposits are found in a paludal deposit that formed in the fans of intermittent drainages, here identified as No Name Arroyo and Big Wash.

5.1 Soils and Geomorphology

Incision of the main Water Canyon bajada (Stratum 1) likely began sometime before 42,000 years ago and the initial formation of the site landscape (cutting and filling associated with deposition of Strata 2 and 3) probably took place ~30,000 years ago (Figure 4). Deep incision then followed and there was at least one phase of alluvial deposition (Stratum 4) inset against the original Water Canyon bajada. This deposit is dated to ~18,000 yr, but soil development suggests that it could be older. It was incised and left as remnant benches in Locus 1 South and in Locus 3 (Figure 4). Stratum 5 alluvium is inset against Stratum 4.

Buried, in situ archaeological deposits are found in paludal mud (Stratum 6). The most common facies is black to very dark gray, but an underlying olive green or gleyed facies is present atop Stratum 5 gravels, and a lighter gray facies is on top of the black facies. The darker colors and fine-grained nature of much of Stratum 6 suggest the slow aggradation of fines, including alluvium and perhaps dust, under wetland conditions. The green coloration seen locally in Stratum 6 is due to iron reduction (gleying) under conditions of a high water table and
abundant organic matter. The gleying is likely post-depositional and, in at least Locus 1, was superimposed over at least one older disconformity within Stratum 6. The gleying is apparent along the southern flank and, to an extremely limited extent, along the northern flank of the site in proximity to the eroded margins of the bajada. The grayer facies is somewhat sandier than the black and green facies and likely represents a period of aggradation with more coarse alluvial and possibly eolian clastics, diluting the input of organic remains.

Stratum 6 does not represent uninterrupted sedimentation. Several disconformities are apparent. The oldest muds, dated ~11,310 to ~11,030 $^{14}$C yr BP (~13,170 to ~12,895 cal yr BP) and <~10,365 $^{14}$C yr BP (~12,240 cal yr BP), are in Locus 1, on a high bench of Stratum 5 gravel, and suggest several cycles of erosion just before and during the Younger Dryas Chronozone of the Terminal Pleistocene. Above those deposits are more Stratum 6 muds and sandy muds dated ~9750 to ~9200 $^{14}$C yr BP (~11,180 to ~10,390 cal yr BP) and to <~8321 $^{14}$C yr BP (~9365 cal yr BP). Elsewhere in the site, the oldest Stratum 6 deposits are slightly older than ~10,280 $^{14}$C yr BP (~12,005 cal yr BP) (Locus 5) and are on topographically lower Stratum 5 gravel. Thus, the oldest Stratum 6 deposits were removed from much of the site by erosion. In particular, Folsom-age (i.e., dating to the Younger Dryas Chronozone) and older deposits are largely missing with the exception of those on the high bench of Stratum 5 gravel. Mud deposition in Locus 5 then resumed after ~10,280 $^{14}$C yr BP (~12,005 cal yr BP) and continued until <~8395 $^{14}$C yr BP (~9400 cal yr BP). Away from Loci 1 and 5, another cycle of erosion was relatively widespread, given the extent of basal dates in the range of ~9900 to ~9500 $^{14}$C yr BP (~11,310
and ~10,800 cal yr BP) across the site, i.e., there was erosion just prior to that time. The
youngest deposit of Stratum 6 is the younger sandy gray facies, dated ~8395 to ~8050 $^{14}$C yr BP
( ~9400 to ~8940 cal yr BP). The top of Stratum 6 was heavily eroded <~8050 $^{14}$C yr BP, based
on obvious disconformities in stratigraphic exposures and variable dating. The relatively long
and continuous suite of dates for Stratum 6 from the Locus 5 area, beginning at ~10,280 $^{14}$C yr
BP (~12,005 cal yr BP), suggests that this area of the site was spared significant early Holocene
erosion, perhaps because of its position on a divide between No Name and Big Wash Arroyos.

The age range of Stratum 6 along Big Wash is significantly younger than it is on the fan
emanating from the mouth of No Name arroyo. In section 12-9 on the south side of Big Wash,
a base date is ~8810 $^{14}$C yr BP (~9820 cal yr BP). An upper black facies is dated <~8655 and
>~7230 $^{14}$C yr BP (<9620 and >8065 cal yr BP). Above is a layer of dark gray mud dated to
~7230 $^{14}$C yr BP. Wetland conditions apparently persisted much longer (or are better
preserved) along Big Wash. North of the wash in the Windmill Pit is an upland soil facies of
Stratum 6 (with some gleying) dating from ~6500 to ~5600 $^{14}$C yr BP (~7395 to 6385 cal yr BP).
The limited dating suggests that the paleo-wetland shifted north away from the No Name fan
in the early Holocene. There are few dates along Big Wash because there are limited
exposures. Moreover, there are no stratigraphic or geomorphic indicators of significant fan
construction. This seems unusual given the much larger drainage area for Big Wash. But the
swale that defines the wash (as opposed to the channel or arroyo) is also much wider (~82 m)
just above the point at which it widens at the site, compared to No Name Swale (~22 m) just
above where it opens up. No
Name Arroyo is in a position to create a fan, with flow confined to a relatively narrow swale until it reaches the end of the swale and water is no longer confined (a classic setting for a fan). The swale with Big Wash is wider and, as it gets into the site area, it becomes progressively wider. This geomorphic characteristic may have gradually dissipated discharge, rather than changing abruptly (as in the case of No Name Swale).

The characteristics of Stratum 6, as delineated previously, are indicative of a wetland and this interpretation is strongly supported by paleoenvironmental reconstructions based on proxy data recovered from Stratum 6 (Dello-Russo et al. 2016a, 2016b). These proxy data included stable carbon isotopes and other data derived from pollen (Smith 2010, 2012, 2015), land snails and snail eggs (Hall 2015), phytoliths (Yost 2016) and diatoms (Winsborough 2016). The Stratum 6 muds represent the remains of a TPEH wetland environment, characterized by wet meadows bordering a creek or interconnected pools and interspersed with marshy areas, similar to modern cienega ecosystems in the region. Taken as a whole, the record at the Water Canyon site indicates a landscape mosaic of different vegetation communities that, along with the presence of fresh water, would have provided a variety of shrubs, grasses and herbs strongly attractive to browsing bison and other game and non-game animals (Dello-Russo et al. 2016a).

The paleoenvironmental reconstruction suggests the presence of at least local shallow standing water. How this standing water was maintained is unclear. Today the site drainage drops almost 20 meters over a distance of less than 1 kilometer to the confluence with the
main channel of the Water Canyon channel itself. Stream flow is easy to maintain after rains.

The coarse character of Stratum 5 and some of Strata 7 and 8 suggest flashy discharges from
the No Name drainage and likely from Big Wash in the late Pleistocene and in the middle
Holocene. Except for the evidence of erosion, Stratum 6, in striking contrast, is indicative of a
high water table supporting a long-lasting wetland habitat.

Even with a high water table some sort of impoundment downstream from the Water
Canyon site seems likely. The lower Big Wash drainage and, at its mouth, Water Canyon are
both incised into either coarse gravel or bedrock so there are no clues to the terminal
Pleistocene history of either drainage at their confluence. There is some evidence for mass
movement along a bedrock slope failure on the south side of Water Canyon just downstream of
its confluence with Big Wash (David Love, personal communication, 2009). Such a mass
movement could have blocked the drainage and impounded stream flow, but that geologic
record has not been investigated and, in any case, the mass movement is not dated.

Another possible mechanism for impounding the Big Wash drainage is the Water
Canyon system itself. Aggradation of the drainage above, below, and at the confluence with Big
Wash could have impounded flow in Big Wash and also could raise the local water table. Some
fluctuations in the flow along Water Canyon could also account for the evidence of erosion in
Stratum 6.

The Terminal Pleistocene stratigraphic record at Water Canyon contrasts with that from other
localities in the Southwest. The Mockingbird Gap site to the east-southeast (Holliday et al.
2009) and the Scholle site to the northeast (Hall et al. 2012) as well as Murray Springs and other Clovis sites in the upper San Pedro Valley of southeast Arizona (Haynes 2008; Haynes and Huckell 2007) all exhibit conformable stratigraphic sequences for the period ~13,500 to ~10,000 cal years. In particular, the Stratum 6 wetland mud is broadly similar lithologically and chronologically to that proposed for the “black mats” of the San Pedro Valley, the “wet meadow” zone at the Scholle site, and the palustrine muds (stratum 2) at the Mockingbird Gap site. But in detail, Stratum 6 is characterized by several cycles of erosion. Sediments of Younger Dryas age are largely missing and later phases of erosion are indicated between >~9500 ¹⁴C yr BP (>~10,800 cal yr BP) and >~8320 ¹⁴C yr BP (>~9365 cal yr BP). The Younger Dryas erosion may just represent local instability or may be indicative of regional variability at that time (e.g., Meltzer and Holliday 2010). Likewise, the early Holocene cycles of erosion have no direct correlates in the area (Onken 2015).

Strata 7 and 8 represent a return to more energetic cycles of fan deposition and erosion. They are sandier than Stratum 6 and both have common pockets and lenses of gravel. Stratum 7 rests unconformably on Stratum 6 and was truncated by erosion in the middle Holocene (Figure 4). Inset against Stratum 7 (on the north) and burying the eroded surface of Stratum 6 is more sand and gravel (Stratum 8). The erosion that truncated Stratum 7 also produced a deep paleo-arroyo (Figure 6A) that cut down through Stratum 7 and into Stratum 6 in a west-to-east direction across the middle of the site. Stratum 8, which filled the lower portion of the paleogully, is dated to ~6500 yr. A well-expressed soil (A-Bt morphology; the La Jencia Soil) formed
across the surface of the site in Strata 7 and 8.

The cutting and filling cycles of Strata 7 and 8 broadly mirror trends in the evolution of arroyos across the Southwest. Incision, fan construction, and another phase of incision are documented at Water Canyon between 6800 and 6200 yr. Localized and episodic but not necessarily synchronous incision is documented from \( \sim 8000 \) to \( \sim 5600 \) \(^{14}\)C yr BP \( \sim 8900 \) to \( \sim 6400 \) cal yr BP) across the Southwest (e.g., Waters and Haynes 2001; Mann and Meltzer 2007; Onken 2015) and attributed to the evolving Holocene climate, but the specific drivers are debated.

The gross sedimentological evolution of the landforms on which the Water Canyon site is located began with deposition of coarse, high energy, pre-LGM and LGM, Pleistocene gravel in an alluvial fan followed by erosion and then formation of a terminal Pleistocene/early Holocene wetland. Following another phase of erosion, thick sand and gravel deposits accumulated during cut and fill cycles as another fan formed. This stratigraphic trend is roughly similar to stratigraphic sequences across the Southwest and parts of the Great Plains (e.g., Holliday and Mandel 2006; Holliday and Miller 2013).

### 5.2 Archaeology

The Water Canyon archaeological site encompasses five different surface loci (1 South, 2, 3, 4 and 6) and two, possibly more, significant subsurface loci (1 North and 5). The subsurface cultural deposits are in fan sediments and consist of intact, buried Paleoindian materials in a stratified context. The fan contains several significant cultural deposits, including a bed of poorly preserved *Bison sp.* bone with an associated Eden projectile point (Locus 5); and a
possible palimpsest of two additional, but very well-preserved, *Bison sp.* bone beds with associated activity areas consisting of butchered bison bones, flaked and ground stone artifacts and the remains of an ephemeral hearth (Locus 1 North). The bone bed in Locus 5, associated with the Eden point, could be dated between ~9887 and ~9640 \(^{14}\)C yr (~11,305 and ~10,975 cal yr BP), although the projectile point itself is more closely associated with a date of ~8955 \(^{14}\)C yr BP (~10,070 cal yr). The upper portion of the bone processing area in Locus 1 North has a mean age estimate of ~8321 \(^{14}\)C yr BP (~9365 cal yr BP) (based on dated charcoal in the Feature 1 hearth), while the lower portion of that bone processing area is dated ~9240 \(^{14}\)C yr BP (based on dated bone collagen). The Locus 1 North bone bed is upslope of, and stratigraphically above, the Locus 5 bone bed. Clovis and Folsom occupations at the site are evidenced by diagnostic projectile point fragments documented in Loci 6 and 3, together with a suite of broken blade fragments repurposed into small, spurred end scrapers (Collins 1999) documented in Locus 6. Subsurface cultural deposits associated with these artifact types have not yet been identified at the site, although sediments dated to those respective time periods have been identified in Locus 1 North.

Buried, stratified Paleoindian sites are rare in southwestern North America west of the Pecos River. Between the Great Plains (northwest Texas/eastern New Mexico) to the east and the San Pedro Valley (Arizona) to the west, only two others are reasonably well-documented and both are in New Mexico: Boles Wells, a Folsom occupation in the Tularosa Basin just south of Alamogordo (Mauldin and O’Leary 1994; Amick et al. 1996, 1998), and LA111429, a Folsom
camp site in the Jornada del Muerto, southeast of the town of Truth or Consequences (Figure 1) (Akins and Moore 2012: 82-98; Moore and Akins 2014). Sandia Cave (Figure 1) probably had intact and stratified Paleoindian deposits, but they were obscured by animal burrowing (Haynes and Agogino 1986) and the archaeological record was further mired in controversy (Preston 1995). A buried Cody occupation may be preserved at the R-6 site near Las Vegas, New Mexico (Figure 1) (Stanford and Patten 1984). None of the aforementioned sites west of the Great Plains are securely dated nor are the stratigraphic contexts clear, however. So, the lack of dateable Paleoindian deposits from buried, multi-component stratified contexts makes the discoveries at the Water Canyon site all the more significant.

The Water Canyon site contains two Paleoindian bison bone beds (one of which is a possible palimpsest of two distinct processing events and the second which is the remains of a kill), another rarity west of the southern Great Plains in New Mexico and Arizona. Bison kills are stereotypical characteristics of Paleoindian sites on the Southern Great Plains and across the Southwest, expressed both as buried bone beds (Hester 1972; Johnson 1987; Jodry 1999; Meltzer 2006; Haynes and Huckell 2007; Holliday et al. 2017) and surface assemblages of bison tooth enamel or highly fragmented and desiccated bison skeletal elements (Beckett 1980; Holliday et al. 2006, 2009; Huckell et al. 2008). The Water Canyon site is thus unique west of the Pecos River in New Mexico for the reasons cited above and because it contains rare, intact, open air processing areas.

6 SUMMARY
The Water Canyon site is a buried, multi-component, stratified Paleoindian site in the Southwestern United States. The archaeological materials are within an alluvial fan at the toe of a large bajada. It contains three late Paleoindian occupation features in ancient paludal deposits on and beneath coarser, higher energy deposits more typical of an alluvial fan. The oldest, well-dated occupation zone, at ~9240 \(^{14}\)C yr BP (~10,390 cal yr BP), is a bed of Bison sp. bones on the margin of the ancient wetland, interpreted as an open-air processing station. A nearby Bison sp. bone bed, farther out in the paleo-wetland and downslope from the processing station, and a probable kill site with an in situ Eden projectile point, currently dates to ~8955 \(^{14}\)C yr BP (~10,070 cal yr), but it may be older. It may be functionally related to the older processing area. The youngest, well-dated occupation level, at ~8321 \(^{14}\)C yr BP (~9365 cal yr BP), is also along the margins of the paleo-wetland and may also contain processed Bison sp. bone and a hearth. Both Clovis and Folsom artifacts have been found on the surface of the site, and remnants of both Clovis- and Folsom-aged paludal strata are preserved in the site but may be of limited extent. Nevertheless, the data show that the palustrine environment that interrupted fan construction attracted ancient foragers since at least ~11,000 \(^{14}\)C yr BP (late Clovis time) through the early Holocene.
FUNDING SOURCES

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ACKNOWLEDGMENTS

This research was conducted through several field permits issued to RDR since 2008 by the New Mexico State Historic Preservation Division and the Energetic Materials Research and Testing Center of the New Mexico Institute of Mining and Technology. Geoarchaeological field assistance was provided by William T. Reitze and Andrew J. Richard. The authors jointly thank the following people for their helpful advice or collaboration, without which our current understanding of the Water Canyon site would not have been possible: Patrice Walker Dello-Russo, Ron Goble, Paul Goldberg, C. Vance Haynes, and Jill Onken. VTH thanks Bruce Huckell and Greg Hodgins, and RDR thanks Mike Collins, Russell Greaves, Stephen Hall, David Love, Les McFadden, Keith Prufer, David Rachal, and Christian Solfisburg. Figures 1, 5, 8, and 9 were created by Jim Abbott; Figures 3A, 3B, 6A, and 6B were jointly created by RDR and VTH; Figures 2, 4, 7, and S1 were created by RDR; Figure 10 was jointly created by RDR and Scott Gunn; and Figure 11 was jointly created by RDR, Alex Kurota and Scott Gunn. The manuscript was
improved by a review from Lee Nordt and two anonymous reviewers.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

FIGURE CAPTIONS

Figure 1. Geographic setting of the Water Canyon site west of the Rio Grande in central New Mexico illustrating the general geomorphic features of the area (based on Machette 1988: figure 1). Inset shows the location of the figure area (dashed rectangle) in New Mexico along with archaeological sites mentioned in the text: BW = Boles Wells; C = Clovis (Blackwater Draw Locality 1); F = Folsom; LA = LA111429; R6 = R-6 site; S = Sandia Cave; SJ = San Jon; WM = Williamson-Plainview and Milnesand.

Figure 2. Topographic map of the Water Canyon site showing locations of: (A) Loci, soil sections, and lines of sections A-A’ (Figure 7) and B-B’ (Figure 8) and (B) excavation blocks and backhoe trenches (BHT). See Figure S1 for locations of all cores.

Figure 3. Views overlooking the Water Canyon site. (A) View to the north with excavations
under way in Locus 1. The area from the foreground north to Big Wash is the surface of the Terminal Pleistocene/Holocene fan encasing the buried archaeological materials, inset well below the surface of the Pleistocene bajada where Locus 6 is situated. (B) View east down No Name Arroyo at the head of the Terminal Pleistocene/Holocene fan showing the exposure of Strata 4, 6, and 8 (with 6 pinching out against 4) at section 10-30 with Locus 1N immediately beyond and the north end of BHT 6 (Figure 2B) visible at right center. Exposure of Unit 1-47 in Locus IN (Figure 2B) is on the opposite arroyo wall.

Figure 4. Late Pleistocene and early Holocene landscape evolution sequence. (A) Original Magdalena fan (bajada) surface on Stratum 1 at > 100 kya. (B) Paleo-channel incises Stratum 1 at >42.0k yr BP; Stratum 2 sediments fill paleo-channel at ~40.0k years BP. (C) Paleo-channel incises Stratum 2 at <40.0 kya; Stratum 3 sediments fill paleo-channel at ~30.0 kya. (D) Initial incision of Big Wash between ~30.8k and ~18.0k years BP. (E) Initial incision of No Name Arroyo at <18k years BP; Deposition of Stratum 4 at or <18.0k years BP. (F) Shallow bench cut on Stratum 4 then deep incision of Stratum 4 at <18.0k years BP. (G) Construction of Stratum 5 fan at <18.0k to >13.0k cal years BP. H) Paludal deposition of Stratum 6 at ~13.1k through ~ 8.0k cal years BP. (I) Deposition and erosion of Strata 7 and 8 from ~8.0k cal years BP to present.

Figure 5. Lithostratigraphy and soil stratigraphy exposed in a segment of Backhoe Trench 6 in Locus 1 (Figures 2B, 3B) illustrating position of OSL sample, erosion on Stratum 4, inset
relationship of Stratum 6 against Stratum 4, and facies relationship of Stratum 6 and its soil facies. Secondary calcium carbonate is common throughout Strata 4 and 6 as films and threads.

Figure 6. (A) The west wall of the Locus 5 excavation block (Figure 2B) illustrating the stratigraphic relationships of Strata 6 (black and gray facies), 7, and 8, and paleo-arroyo. (B) Close-up of the excavations (Units 5-1, 5-6 and 5-8) and profile in the southwest corner of the Locality 5 excavations (keyed to Figure 6A), illustrating the bottom of paleo-arroyo infilled with laminated sediments of Stratum 8 and inset into Stratum 6, a portion of the Bison sp. bone bed (Unit 5-8), and Stratum 5 cobbles beneath the black facies of Stratum 6.

Figure 7. Generalized stratigraphic sequence of the Water Canyon site along section A-A’ (Figure 2A) running northeast from Locus 1 South.

Figure 8. Generalized stratigraphic sequence of the Water Canyon site along section B-B’ running east-southeast from Locus 1 North (Figure 2A), illustrating the change in elevation across the top of Strata 5 and 6. Radiocarbon means are provided for the base of Stratum 6 in cores 9-10, 9-11, and 10-26 (Table 2).

Figure 9. Lithostratigraphy and soil stratigraphy exposed in Backhoe Trench 4 east of Locus 3 (Figure 2B) illustrating position of OSL samples, erosion on Stratum 4, and sloping fan-like
character and facies of Stratum 5. Secondary calcium carbonate is common throughout Stratum 5 and 6 as films and threads.

Figure 10. An example of the black and olive green (gleyed) facies of Stratum 6 along the North wall of Unit 1-47 on the north side of No Name Arroyo in Locus 1 North (Figures 2B, 3B). Cobbly Stratum 5 is overlain by the olive facies of Stratum 6 (6A) and, above, the black facies (6B). The dot on the aluminum can is the location for radiocarbon sample A-15021 (Table 2). It and the other sampling locations (dots) are labeled with their respective mean dates (Table 2).

Figure 11. West-to-east backplot of dated and undated bones, artifacts, and charcoal in Locus 1 North. Dates for bone collagen and Feature 1 hearth are in $^{14}$C yr BP (Table 2). Shaded areas illustrate inferred groupings of different age bone beds (upper and lower) and eastern-most bone cluster. Unshaded areas between bone beds/cluster represent inferred disconformities. The three bone collagen dates in the lower bone bed (bone cluster 2) are statistically the same ($t=0.823$) and their mean radiocarbon date is statistically different ($t=26.765$) than that of the bone collagen sample in the upper bone bed Bone cluster 1). The bone collagen date in the upper bone bed is statistically different than ($t=7.466$), but only slightly younger than, the Feature 1 hearth in the same bone bed. The third potential bone cluster, on the eastern side of Figure 11 (Bone cluster 3), has two dated bone collagen samples that are only slightly different in age ($t=4.446$) but whose mean date is very different than both the upper ($t=82.239$) and
lower \( t=128.228 \) bone beds.

Figure 12. Bison bone found within the black facies of Stratum 6 in core 10-1 (Figure S1). The mud that encased the bone produced radiocarbon samples AA-95610 and Beta-317339 (Table 2).

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Table 1. Selected stratigraphic descriptions from the Water Canyon site, south (core 9-02) to north (section 12-09).

**Core 9-02, Locus 1 South**

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Depth, cm</th>
<th>Soil Horizona</th>
<th>Descriptionb</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0-3</td>
<td>C</td>
<td>loose fS; sl redder than 10YR 4/4sm; abrupt bndy</td>
</tr>
<tr>
<td>8 with</td>
<td>3-8</td>
<td>A</td>
<td>fSL; brown 7.5YR 4/3sm; str cr &amp; wk sbk; clear bndy</td>
</tr>
<tr>
<td>表面土</td>
<td>8-28</td>
<td>Bt</td>
<td>SCL w/few rock frags; brown 7.5YR 4/4d; wk med pr &amp; str med sbk; thin cont clay films on ped faces &amp; rock clasts; clear bndy</td>
</tr>
<tr>
<td>28-48</td>
<td>Bt wk</td>
<td>SCL; brown 10YR 5/3d; v wk pr &amp; str med sbk; thin patchy clay films; few carb films &amp; thr; clear bndy</td>
<td></td>
</tr>
<tr>
<td>48-68</td>
<td>Bw1</td>
<td>fSL; brown 10YR 5/3d; v wk pr &amp; str med sbk; clear bndy</td>
<td></td>
</tr>
<tr>
<td>68-81</td>
<td>Bw2</td>
<td>fSL; brown 10YR 5/3d; v wk pr &amp; wk sbk; clear bndy</td>
<td></td>
</tr>
<tr>
<td>6 黑/灰</td>
<td>81-109</td>
<td>Ak1b1</td>
<td>mud w/common sl rounded rock frags; dark brown 7.5YR 4/2sm; wk med abk; common faint carb films &amp; thr on ped faces and rock frags (indistinct owing to slightly moist soil); clear bndy PW</td>
</tr>
<tr>
<td></td>
<td>109-136</td>
<td>Ak2b1</td>
<td>mud w/common slightly rounded rock frags; brown 7.5YR 5/3d matrix; med mod abk; almost cont carb coatings on ped faces &amp; rock frags; clear bndy PW</td>
</tr>
<tr>
<td></td>
<td>136-183</td>
<td>Ak3b1</td>
<td>mud w/v common rock frags; brown 7.5YR 5/3d; med mod abk; carb coats not as cont but still prominent; v common Fe-ox stains; 10YR 5/6d; clear bndy PW</td>
</tr>
<tr>
<td></td>
<td>183-208</td>
<td>Ak4b1</td>
<td>as above but fewer rock frags; clear bndy PW</td>
</tr>
<tr>
<td></td>
<td>208-256</td>
<td>Ak5b1</td>
<td>as above but fLS and no rock frags; some platiness below 240cm; upper 10cm grades from the overlying mud down to the f loamy sand; common carb films on ped faces; clear bndy PW</td>
</tr>
<tr>
<td></td>
<td>256-280</td>
<td>Ak6b1</td>
<td>as above but less f sand w/depth; by 280 f sandy mud; common carb films on ped faces; clear bndy PW</td>
</tr>
</tbody>
</table>
### Locus 1 North, Section 10-30 (corner with No Name Arroyo)

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Thickness, cm</th>
<th>Soil Horizon&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Description&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/8</td>
<td>21</td>
<td>Bt</td>
<td>Gravelly SCL; dark brown 7.5YR 4.5/d; v wk pr &amp; mod med sbk; thin patchy clay films; clear bndy</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Bw</td>
<td>SCL; brown 7.5YR 5/4d; mod med sbk; scattered gravel; clear bndy</td>
</tr>
<tr>
<td>6 gray</td>
<td>23</td>
<td>ABk1b1</td>
<td>Mud; brown 7.5YR 4/3d; wk cse sbk; common faint carb films &amp; thr; clear bndy</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>ABk2b1</td>
<td>SCL, gravel common; slighty grayer than brown 7.5YR 4/3dsm; common faint carb films &amp; thr; clear bndy</td>
</tr>
<tr>
<td>6 black&lt;sup&gt;d&lt;/sup&gt;</td>
<td>25</td>
<td>Ab1</td>
<td>Mud&lt;sup&gt;c&lt;/sup&gt; dark gray 10YR 4/1d; f str sbk; common fine patches of carb; clear, smooth bndy PW</td>
</tr>
<tr>
<td>6 green</td>
<td>30</td>
<td>Cgb1</td>
<td>S mud, locally gravelly; gray brown 2.5Y 5.5/2d (transition from Ab to Cb); massive; clear, smooth bndy PW</td>
</tr>
<tr>
<td>5</td>
<td>20+</td>
<td>Cb1</td>
<td>S mud; gray brown 10YR 5/2d w Fe-ox mottles of brownish yellow 10YR 6/6d; massive</td>
</tr>
</tbody>
</table>

### Locus 5 pit, Section 13-03 (just N of center of W wall)

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Depth, cm</th>
<th>Soil Horizon&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Description&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0-3</td>
<td>A</td>
<td>SCL, brown 7.5YR 4/4d; f mod sbk &amp; wk gr; clear bndy</td>
</tr>
<tr>
<td></td>
<td>3-17</td>
<td>Bt</td>
<td>SCL, strong brown 7.5YR 4/6d; f wk pr &amp; f mod sbk; common thin clay films; clear bndy</td>
</tr>
<tr>
<td>Stratum</td>
<td>Depth, cm</td>
<td>Horizon</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>17-30</td>
<td>Btw</td>
<td>SCL, brown 7.5YR 4.5/4d; med str sbk &amp; v wk cse pr; common carb films &amp; thr; thin patchy clay films; clear bndy</td>
<td></td>
</tr>
<tr>
<td>30-60</td>
<td>C1</td>
<td>loose sand &amp; gravel; 7.5YR 5.5/4d; abrupt bndy</td>
<td></td>
</tr>
<tr>
<td>60-75</td>
<td>C2</td>
<td>mS w/fine gravel; 7.5YR 5.5/4d; abrupt bndy</td>
<td></td>
</tr>
<tr>
<td>75-90</td>
<td>C3</td>
<td>massive cse gravel; abrupt bndy (90cm = top of upper bench)</td>
<td></td>
</tr>
<tr>
<td>90-135</td>
<td>C4</td>
<td>massive fSL; 7.5YR 5.5/4d; abrupt bndy</td>
<td></td>
</tr>
<tr>
<td>135-160</td>
<td>C5</td>
<td>pocket of gravel; abrupt bndy</td>
<td></td>
</tr>
<tr>
<td>160-177</td>
<td>C6</td>
<td>f gravel &amp; cS; 7.5YR 5.5/4d; abrupt bndy</td>
<td></td>
</tr>
<tr>
<td>177-200</td>
<td>C7</td>
<td>loose fSL; 7.5/10YR 5.5/6d; v wk sbk; abrupt bndy (200cm = top of lower bench)</td>
<td></td>
</tr>
<tr>
<td>200-220</td>
<td>C8</td>
<td>lens of cse, dense rubble (cse sand to left &amp; right); abrupt bndy</td>
<td></td>
</tr>
<tr>
<td>220-238</td>
<td>C9</td>
<td>LfS w cS &amp; f pebbles; 10YR 5.5/2d; abrupt bndy</td>
<td></td>
</tr>
</tbody>
</table>

6 gray

238-273 | Ab1       | LfS; brownish gray 10YR 6/2d; wk med sbk; local, disc gravel clasts at base; fine carb root casts in lower 5cm; abrupt, wavy bndy PW

6 black

273-300 | Ab2       | S mud; dark gray 10YR 4/1d; med mod sbk to abk; few faint carb films (300 cm, bottom of pit) PW

Section 12-09 (Big Wash)

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Depth, cm</th>
<th>Soil Horizon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7?</td>
<td>0-50</td>
<td>A-Btw?</td>
<td>SL w/common rocks; dark brown 7.5YR 3/3m; wk pr &amp; wk sbk; clear bndy</td>
</tr>
<tr>
<td></td>
<td>50-65</td>
<td>Bk</td>
<td>As above w few films &amp; thr carbonate; abrupt, wavy bndy</td>
</tr>
<tr>
<td></td>
<td>65-160</td>
<td></td>
<td>loose sand and gravel w some rock rubble; abrupt, wavy bndy</td>
</tr>
<tr>
<td>6 gray/black</td>
<td>160-180</td>
<td></td>
<td>dark gray brown SCL; dark grayish brown 2.5Y 3/2m; clear, smooth bndy PW</td>
</tr>
<tr>
<td>Stratum</td>
<td>Color and Texture Description</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>180-185</td>
<td>black SCL; very dark gray 2.5Y 3/1m; faint bedding; wavy, abrupt bndy</td>
<td>PW</td>
<td></td>
</tr>
<tr>
<td>185-191</td>
<td>medium gray SCL; dark grayish brown 2.5Y 4/2m; wavy, abrupt bndy</td>
<td>PW</td>
<td></td>
</tr>
<tr>
<td>191-205</td>
<td>black SCL; very dark gray 2.5Y 3/1m; faint bedding; v wavy, abrupt bndy</td>
<td>PW</td>
<td></td>
</tr>
<tr>
<td>6 green</td>
<td>dark olive SCL; dark olive brown 2.5Y 3/3m</td>
<td>PW</td>
<td></td>
</tr>
</tbody>
</table>

Variations to standard USDA horizon nomenclature follow Holliday (2004, appendix 1).

Abbreviations for descriptions:

- Colors = Munsell d = dry; sm = slightly moist; m = moist
- Textures: S = Sand; SL = Sandy Loam; SCL = Sandy Clay Loam; f = fine;
- Structure: cr = crumb; sbk = subangular blocky; abk = angular blocky; pr = prismatic; wk = weak; mod = moderate; str = strong; f = fine; med = medium; cse = coarse;
- Miscellaneous descriptors: bndy = boundary; carb = carbonate; cont – continuous; disc = discontinuous; Fe-ox = iron oxides; frags = fragments; sl = slightly

PW = Paleo-wetland deposits/soils

Black Stratum 6 has increasing amounts of gravel moving east to west (i.e., upstream).
Table 2. Radiocarbon and optically stimulated luminescence dates from the Water Canyon site (see also Tables S1 and S2).

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Grid Elev. (m)</th>
<th>Material</th>
<th>F.S. Number</th>
<th>Lab Number</th>
<th>C yr B.P.</th>
<th>Relative Area</th>
<th>Cal yr B.P.</th>
<th>Relative Area</th>
<th>Cal yr B.P.</th>
<th>Relative Area</th>
<th>Mean Highest 2-sigma Probability (Cal yr B.P.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOCUS 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td><strong>Unit 1-9, 14C</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 black</td>
<td>48.03</td>
<td>SOM</td>
<td>1274</td>
<td>AA103849</td>
<td>9310±52</td>
<td>10,508-10,524</td>
<td>10,498-10,568</td>
<td>10,530-10,553</td>
<td>0.437</td>
<td>0.563</td>
<td>10,533±35</td>
</tr>
<tr>
<td>47.82</td>
<td>SOM</td>
<td>1273</td>
<td>AA103848</td>
<td>9482±62</td>
<td>10,596-10,624</td>
<td>10,572-10,881</td>
<td>10,650-10,791</td>
<td>11,026-11,064</td>
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### Unit 1-11, $^{14}$C (Feature 1 hearth)

| 6 gray | 48.25 | Charcoal | 1036 | AA94458 | 8354±58 | 9304-9365 | 9367-9450 | 0.424 | 0.576 | 9142-9175 | 9207-9220 | 9238-9494 | 0.027 | 0.008 | 0.964 | 9366±128 |
| 48.23 | Charcoal | 1049 | AA94459 | 8349±49 | 9305-9364 | 9369-9439 | 0.469 | 0.531 | 9150-9166 | 9249-9484 | 0.011 | 0.989 | 9367±118 |
| 48.22 | Charcoal | 1051 | AA94460 | 8314±56 | 9269-9430 | 9433-9526 | 1.000 | 9137-9187 | 9191-9463 | 0.988 | 0.912 | 9327±136 |
| 48.23 | Charcoal | 1052 | AA94461 | 8447±64 | 9433-9526 | 9537-10,000 | 0.027 | 0.978 | 9467±74 |
| 48.20 | Charcoal | 1053 | AA94462 | 824±52 | 9287-9429 | 9303-9430 | 1.000 | 9139-9178 | 9201-9228 | 0.954 | 0.919 | 9350±119 |
| 48.20 | Charcoal | 1054 | AA94463 | 8385±48 | 9321-9354 | 9400-9476 | 0.237 | 0.763 | 9286-9499 | 1.000 | 9393±107 |
| 48.20 | Charcoal | 1055 | AA94464 | 8346±51 | 9304-9436 | 9304-9436 | 1.000 | 9145-9172 | 9242-9484 | 0.022 | 0.978 | 9363±121 |
| 48.19 | Charcoal | 1058 | AA94465 | 8338±48 | 9303-9430 | 9303-9430 | 1.000 | 9145-9173 | 9241-9477 | 0.024 | 0.976 | 9359±118 |
| 48.15 | Charcoal | 59b | AA94466 | 8186±47 | 9031-9141 | 9175-9206 | 0.712 | 0.183 | 0.105 | 9017-9276 | 1.000 | 9147±130 |
| 48.15 | Charcoal | 59a | Beta-288067 | 8280±50 | 9141-9174 | 9208-9217 | 0.152 | 0.041 | 0.490 | 9094-9100 | 9121-9436 | 0.004 | 0.996 | 9279±158 |

--- mean 8321±19 --- --- --- --- --- --- --- --- --- --- ---

### Unit 1-12, $^{14}$C

| 48.17 | Charcoal | 1066 | AA94467 | 9454±51 | 10,589-10,630 | 10,646-10,750 | 0.238 | 0.762 | 10,560-10,800 | 10,851-10,863 | 10,957-11,067 | 0.886 | 0.007 | 0.107 | 10,680±120 |

### Unit 1-20, $^{14}$C

<p>| 48.00 | Bone collagen | 1613 | PSU-3564 | 9180±60 | 10,250-10,402 | 1.000 | 10,234-10,500 | 1.000 | 10,367±133 |
| 47.88 | Bone collagen | 1605 | PSU-3567 | 8810±70 | 9695-9934 | 9959-10,004 | 0.819 | 0.023 | 0.157 | 9613-9617 | 9621-10,161 | 0.003 | 0.997 | 9891±270 |</p>
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### LOCUS 2

**BT 5, OSL**

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### LOCUS 5

**Locus 5, main pit, OSL**

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**Locus 5, main pit, $^{14}$C²**

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### EAST of LOCUS 5

#### Core 10-1, $^{14}$C

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#### Core 10-6/7, $^{14}$C

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<td>45.83</td>
<td>SOM</td>
<td>67</td>
<td>A-15623</td>
<td>8255±140</td>
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<tr>
<td>45.63</td>
<td>SOM</td>
<td>69</td>
<td>A-15624</td>
<td>8305±90</td>
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<tr>
<td>45.33</td>
<td>SOM</td>
<td>72</td>
<td>A-15625</td>
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<tr>
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<td>SOM</td>
<td>73</td>
<td>A-15626</td>
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</tr>
<tr>
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<td>SOM</td>
<td>75</td>
<td>A-15627</td>
<td>8940±75</td>
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#### Core 6/5

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<td>9405+70/-65</td>
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<tr>
<td>44.69</td>
<td>SOM</td>
<td>79</td>
<td>A-15629</td>
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### NORTHEAST of LOCUS 5

#### Core 09-18, $^{14}$C

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<th>Code</th>
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<th>Depth Range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Black</td>
<td>SOM</td>
<td>1082</td>
<td>A-15341</td>
<td>8590±95</td>
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#### Section 12-9, $^{14}$C
<table>
<thead>
<tr>
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<th>BHT 4, OSL</th>
<th>Windmill Pit, $^{14}$C</th>
<th>BIG WASH, $^{14}$C</th>
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<tr>
<td>?? 8?</td>
<td>50.80 Quartz</td>
<td>47.85 SOM 26 A-15303 5600±50</td>
<td>47.75 SOM 27 A-15304 6500±80</td>
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<tr>
<td>5</td>
<td>50.46 Quartz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>49.99 Quartz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 black upland</td>
<td>4.80 SOM 1331 AA106885 6126±28</td>
<td></td>
<td></td>
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</tbody>
</table>

1 SOM = soil organic matter
2 Units 5-1, 5-3 & core 10-2/3
3 Sediment associated with bone; Split of same sample; charcoal was mixed in with sediment
4 Estimate derived from a GPS coordinate in feet
Table 3. Projectile Points recovered from Water Canyon site.

<table>
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<tr>
<th>Point Type</th>
<th>Cultural Period</th>
<th>Provenience</th>
<th>Frequency</th>
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<td>Base / silicified rhyolite</td>
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<td>Loci 3, 6 / surface</td>
<td>2</td>
<td>Fragment / silicified rhyolite</td>
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<tr>
<td>Eden / Firstview</td>
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<td>Locus 5 / In situ, sub-surface</td>
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<td>Complete, resharpened, broken tip; quartzite</td>
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<tr>
<td>Eden / Firstview</td>
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<td>Locus 4 / surface</td>
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<td>Base, silicified rhyolite</td>
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<tr>
<td>Undetermined</td>
<td>Late Paleoindian (probable)</td>
<td>Locus 4 / surface</td>
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<td>Preform; shallow, convex-sided, concave base; preform; quartzite</td>
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<tr>
<td>Undetermined</td>
<td>Late Paleoindian (probable)</td>
<td>Locus 3 / surface</td>
<td>2</td>
<td>Small; parallel-sided; shallow, concave bases; 1 black chert complete but heavily resharpened; other obsidian lateral fragment; similar to Angostura, Golondrina, Belen, St. Mary’s Hall</td>
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<td>Gypsum</td>
<td>Archaic</td>
<td>Loci 2, 3 / surface</td>
<td>2</td>
<td>Stemmed; made on flakes</td>
</tr>
<tr>
<td>Armijo</td>
<td>Archaic</td>
<td>Loci 1, 4 / surface</td>
<td>2</td>
<td>Concave base</td>
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</tbody>
</table>
Figure 2. Topographic map of the Water Canyon site showing locations of: (A) Loci, soil sections, and lines of sections A-A’ (Figure 7) and B-B’ (Figure 8) and (B) excavation blocks and backhoe trenches (BHT). See Figure S1 for locations of all cores.

158x204mm (200 x 200 DPI)
Figure 2. Topographic map of the Water Canyon site showing locations of: (A) Loci, soil sections, and lines of sections A-A’ (Figure 7) and B-B’ (Figure 8) and (B) excavation blocks and backhoe trenches (BHT). See Figure S1 for locations of all cores.

158x204mm (200 x 200 DPI)
Figure 3. Views overlooking the Water Canyon site. (A) View to the north with excavations under way in Locus 1. The area from the foreground north to Big Wash is the surface of the Terminal Pleistocene/Holocene fan encasing the buried archaeological materials, inset well below the surface of the Pleistocene bajada where Locus 6 is situated. (B) View east down No Name Arroyo at the head of the Terminal Pleistocene/Holocene fan showing the exposure of Strata 4, 6, and 8 (with 6 pinching out against 4) at section 10-30 with Locus 1N immediately beyond and the north end of BHT 6 (Figure 2B) visible at right center. Exposure of Unit 1-47 in Locus 1N (Figure 2B) is on the opposite arroyo wall.
Figure 4. Late Pleistocene and early Holocene landscape evolution sequence. (A) Original Magdalena fan (bajada) surface on Stratum 1 at > 100 kya. (B) Paleo-channel incises Stratum 1 at >42.0k yr BP; Stratum 2 sediments fill paleo-channel at ~40.0k years BP. (C) Paleo-channel incises Stratum 2 at <40.0 kya; Stratum 3 sediments fill paleo-channel at ~30.0 kya. (D) Initial incision of Big Wash between ~30.8k and ~18k years BP. (E) Initial incision of No Name Arroyo at <18k years BP; Deposition of Stratum 4 at or <18.0k years BP. (F) Shallow bench cut on Stratum 4 then deep incision of Stratum 4 at <18.0k years BP. (G) Construction of Stratum 5 fan at <18.0k to >13.0k cal years BP. (H) Paludal deposition of Stratum 6 at ~13.1k through ~ 8.0k cal years BP. (I) Deposition and erosion of Strata 7 and 8 from ~8.0k cal years BP to present.
Figure 6. (A) The west wall of the Locus 5 excavation block (Figure 2B) illustrating the stratigraphic relationships of Strata 6 (black and gray facies), 7, and 8, and paleo-arroyo. (B) Close-up of the excavations (Units 5-1, 5-6 and 5-8) and profile in the southwest corner of the Locality 5 excavations (keyed to Figure 6A), illustrating the bottom of paleo-arroyo infilled with laminated sediments of Stratum 8 and inset into Stratum 6, a portion of the Bison sp. bone bed (Unit 5-8), and Stratum 5 cobbles beneath the black facies of Stratum 6.
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GEOARCHAEOLOGY OF THE WATER CANYON PALEOINDIAN SITE, WEST-CENTRAL NEW MEXICO

by Vance T. Holliday1*, Robert D. Dello-Russo2, and Susan M. Mentzer3

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Abstract

Water Canyon is a rare buried, multi-component, stratified Paleoindian site in west-central New Mexico. This paper presents a geoarchaeological assessment of the site as part of a broader interdisciplinary investigation of the site’s landscape evolution, geochronology, paleoenvironmental history, and archaeology during the Paleoindian occupation. The archaeology is associated with ancient wetland deposits (Stratum 6) within an alluvial fan. The fan formed initially through the late Pleistocene. Formation of the fan stopped and wetland deposition began ~11,310 14C yr BP (~13,170 cal yr BP). Stratum 6 evolved via wetland deposition and cut-and-fill cycles. The bulk of Stratum 6 dates <10,300 14C yr BP (<12,200 cal yr BP). One, or possibly two, beds of bison bone, likely processing-stations, were found on the margin of the paleo-wetland and date to ~9200 14C yr BP (~10,400 cal yr BP) (lower bone bed) and ~8200 14C yr BP (~9150 cal yr BP) (upper bone bed). Farther out in the paleo-wetland a
probable kill site was discovered with an in situ Eden projectile point dated to at least ~8955 \(^{14}\)C yr BP (~10,070 cal yr BP). The wetland landscape returned to an alluvial fan system <8000 \(^{14}\)C yr BP (<8900 cal yr BP) with two more cycles of fan deposition by ~6500 cal yr.

Key Words: alluvial fan; paleo-wetland; bison kill; bison processing; Paleoindian; Eden point

1 INTRODUCTION

Paleoindian archaeological research in North America has been significantly influenced by work in the greater Southwest and neighboring areas\(^1\). The Folsom type site, which resolved the debate over a late Pleistocene human presence in the Americas, is in northeast New Mexico (Figgins 1927; Meltzer 2006). The Clovis type site at Blackwater Draw, with a rich record of long-term Paleoindian occupation that established the classic Clovis-Folsom-unfluted artifact sequence, is in east-central New Mexico (Hester 1972; Howard 1933, 1935). In the heart of the Southwest, in situ, stratified Paleoindian sites are rare. Exceptions include the San Pedro River valley in southeastern Arizona, with at least four Clovis mammoth kills (e.g. Haynes and Huckell 2007), and in northern Sonora, Mexico, a Clovis-gomphothere kill and camp site is reported (Sanchez et al. 2014). To the north, in the San Luis Valley of Colorado, are Folsom age bison kill /

\(^1\) Geologically, the Basin and Range country west of the Pecos River Valley to the foot of the Sierra Nevada is one definition of the Southwest in the U.S. More informally, Reed (1964) offers a useful shorthand definition of the Southwest as extending from Durango, Colorado, to Durango, Mexico, and from Las Vegas, New Mexico, to Las Vegas, Nevada.
campsites, such as Stewart’s Cattle Guard site (Jodry 1999).

Paleoindian archaeology in the American Southwest is challenged by the rarity of terminal Pleistocene and early Holocene paleoenvironmental data from continuous stratigraphic sequences. Except for Clovis mammoth hunting, the chronologies for artifacts and occupations and the nature of subsistence activities must often be inferred from neighboring regions, usually the Great Plains to the east (e.g., Haynes 1975; Johnson 1987; Holliday 2000; Meltzer 2006; Haynes and Warnica 2012). The region’s paleovegetation and paleoclimate data tend to come from discontinuous records (e.g., packrat middens) and the sources of both types of paleoenvironmental data are widely scattered.

Here we report on the Water Canyon site in west-central New Mexico (Figure 1) (Dello-Russo et al. 2010). The site is unusual in the region, yielding evidence for multiple Paleoindian activity areas spanning the period from ~11,000 to ~8300 radiocarbon years before present ($^{14}$C yr BP) or ~13,000 to ~9200 calendar years before present (cal yr BP). Bone and stone artifacts, plant remains, and other classes of paleoenvironmental proxy data such as pollen, phytoliths, diatoms, stable carbon isotopes and land snails, were recovered from stratified, dateable deposits (Dello-Russo 2010, 2012, 2015; Dello-Russo et al. 2016a, 2016b). The in situ Paleoindian components, buried in wetland deposits, are immediately adjacent to upland surfaces with additional evidence for Paleoindian activities. This paper focuses primarily on the stratigraphic and geochronologic record as they inform on the landscape evolution of the site and archaeological formation processes.
1.1 Site Location and Setting

The Water Canyon site is in west-central New Mexico on the southeast side of the La Jencia Basin just west of the Socorro Mountains and at the toe of an extensive bajada on the northeast side of the Magdalena Mountains (Figure 1). The site is along a tributary of the Water Canyon drainage which is, in turn, part of a tributary system of the Rio Grande (Machette 1988). The Water Canyon drainage heads on the northeast side of the Magdalena Mountains and flows east then north across a broad bajada (coalesced alluvial fans). Water Canyon joins South Canyon southeast of and upstream from the Water Canyon site. The combined drainage flows northeast and divides the Socorro Mountains and the Lemitar Mountains, at which point the drainage becomes Nogal Canyon and flows east to join the Rio Grande north of the city of Socorro. The mountains are composed of Oligocene volcanic rock. The volcanism and subsequent faulting, uplift of the mountains, and dropping of the basin are linked to the evolution of the Rio Grande Rift (Chapin et al. 2004; Hawley 2005).

The bajada with the Water Canyon site is known locally as the Water Canyon fan (Chamberlin and Osburn, 2006), but is referred to in this paper as the Water Canyon bajada. The site is currently dissected by three arroyos that formed in and emanate from a series of swales incised into the toe of this bajada (Figures 2, 3A, 3B). “No Name Arroyo”, formed in “No Name Swale”, is the middle of the three and cuts through the middle of the site exposing black paludal muds that led to the discovery of the Paleoindian-age bone and associated artifacts.
A smaller, unnamed arroyo occurs in the southeastern portion of the site. The north side of the site is cut by “Big Wash.” Big Wash and No Name Arroyo converge in the eastern portion of the site. The combined drainages meet the unnamed arroyo at the far eastern edge of the site. From there the drainage flows east another 500 meters to join the main Water Canyon drainage. The site formed where the three aforementioned drainages emerge from narrow arroyos cut into the old bajada deposits.

2 FIELD AND ANALYTICAL METHODS

The geological and geoarchaeological investigations in and near the Water Canyon site included the recognition and mapping of landforms, and the examination, documentation, and dating of the stratigraphic record. All exposures and cores were measured and described using standard geologic and pedologic nomenclature and conventions (Table 1) (AGI 1982; Birkeland 1999; Holliday 2004). The site covers an area of over 9 hectares and is divided into seven “loci” (Figures 2, 3A). Stratigraphic exposures were available from archaeological hand-excavations in three loci (1, 3, and 5); six backhoe trenches (BHT-1, -2, -3 and -6 in Locus 1; BHT-4 in Locus 3; and BHT-5 in Locus 2), 75 cores (via Giddings coring rig), hand augers, and the three arroyos that cut across the site (Figures 2, 3A, 3B, S1). Numerous pollen and radiocarbon samples, together with a few bone samples, were recovered from these various exposures. A micromorphological study of sediments was carried out in Locus 1 (Supporting Information). Most of the archaeological excavations focused on Locus 1 North, along two sides of No Name
Assessing the chronology of the cultural deposits and the site stratigraphy was accomplished using radiocarbon and optically stimulated luminescence (OSL) dating techniques (Table 2). Radiocarbon ages were determined for soil organic matter (SOM) from buried soil horizons and organic-rich sediments, as well as for charcoal and bone collagen samples. The radiocarbon dating of organic-rich sediments can be somewhat problematic owing to the potential for contamination by younger humic acids (Martin and Johnson 1995; Abbot and Stafford 1996; McGeehin et al. 2001) but, with proper pretreatment, these materials can provide accurate, reproducible, stratigraphically consistent age control, especially in drier environments (e.g., Haas et al. 1986; Holliday et al. 1994, 1996; Quade et al. 1998; Rawling et al. 2003; Mayer and Mahan 2004). The Water Canyon SOM samples underwent a standard acid-base-acid treatment to remove carbonate and isolate specific fractions of organic matter (after Abbot and Stafford 1996). Radiocarbon ages were determined for the residue (NaOH insoluble) and humic acid (NaOH soluble) fractions using 1) the liquid scintillation method at the University of Arizona Isotope Geochemistry Laboratory (i.e., conventional radiocarbon; A-#s), and 2) accelerator mass spectrometry (AMS) at the NSF - Arizona AMS Laboratory (AA#s), the Beta Analytic, Inc. laboratory (Beta #s), Pennsylvania State University (PSU-#s), and the International Chemical Analysis laboratory (16OS/ and 16B/#s). Radiocarbon ages were corrected for isotopic fractionation and are presented as uncalibrated radiocarbon years before present (14C yr BP) in the text and in Table 2. Calibrated ages and statistical means were
determined using the CALIB 7.0.4 program (Stuiver and Reimer 1993) and the IntCal 13.14c
database.

Dating by optically stimulated luminescence (OSL) was carried out on sediment samples
by the University of Nebraska – Lincoln (UNL- #s; Goble 2014, 2015) and Utah State University
(USU- #s; Rittenour 2011) (Tables 2, S1, S2). OSL ages are given simply as calendar years (yr) in
the text. Calibrated radiocarbon years are considered to be equivalent to OSL calendar years.

3 RESULTS OF GEOLOGICAL STUDIES

The landforms and strata at the Water Canyon site can be grouped into two categories
defined by age: those created during the older Pleistocene (defined here as Last Glacial
Maximum [LGM] and older), including Strata 1, 2, 3, and 4; and landforms and more localized
strata created in the terminal Pleistocene and early Holocene (TPEH) and later Holocene
epochs (<18,000 yr), consisting of Strata 5, 6, 7 and 8, which are inset against the older strata.

3.1 Older Deposits and Landforms

3.1.1 Strata 1, 2, and 3

The topographic setting in the immediate area of the Water Canyon site is directly or
indirectly related to geomorphic processes that created and modified the large, prominent
Water Canyon bajada that characterizes the landscape of the southern La Jencia Basin (Figures
1, 3A). As noted, the arroyos that dissect the site are parts of drainages incised into the lower
end, or toe, of the Water Canyon bajada. The uplands north of Big Wash and Locus 3, those southwest of Locus 4, west of Locus 1, and the surface of Locus 6, represent the surface of the toe of the Water Canyon bajada (Figure 4A). The bajada sediments (Stratum 1) consist of “poorly to moderately sorted, bouldery to cobbly, volcanic-rich gravel, gravelly sand and muddy silts. [They are] generally reddish orange to reddish brown, locally light brown to tan in color

[and are] mostly non-indurated, however, the uppermost beds beneath its graded surfaces are variably cemented by pedogenic carbonate horizons approximately 0.6 m to 0.1 m thick” (Chamberlin 2005:6). The surface sediments have undergone some modification in the immediate site area where they are characterized by carbonate-engulfed gravel. Less than a kilometer to the west, the Water Canyon bajada surface is covered by sandy fines that display an exceptionally well-developed soil (Bt horizon with red color almost 2.5YR, pervasive illuvial clay, strong structure, and a Bk horizon with Stage III carbonate development). Because the carbonate forms beneath the Bt horizon (Machette 1988), the areas of exposed carbonate on the fan surface (e.g., the surface of Locus 6) are indicative of erosion of the less resistant Bt horizon.

The age of the Water Canyon bajada is estimated at >500,000 to 25,000 years old based on the degree of development of surface and buried soils nearby and radiometric age control elsewhere (Machette 1988). Bajada construction probably ended when drainages in the La Jencia Basin integrated with the Rio Grande through Nogal Canyon (Machette 1988).
broader bajada surfaces to the north, west and south (Figures 2, 3A). The archaeological 
materials at Locus 2 are emplaced on this younger surface which is expressed as a narrow, flat 
ridge roughly two to three meters below the local bajada surface. This surface was created 
when the upper portions of the older bajada deposits were eroded. The sediments underlying 
this ridge represent an early episode of filling (Stratum 2) following incision of the bajada 
surface sometime before 42,000 years ago (Figure 4B; see OSL discussion below). Backhoe 
trench 5 (BHT-5; Figure 2B) exposed a paleochannel in the Stratum 2 fill below this surface 
(Figure 4C). Designated as Stratum 3, the fill in this paleochannel includes sandy, loamy and 
slightly gravelly alluvium inset into the older, coarse, well-sorted and well-rounded gravel of 
Stratum 2. Minimal soil development on this surface suggests that Locus 2 has been 
undergoing continued erosion.

Two OSL ages on the sand indicate that both strata below the Locus 2 surface are pre-
LGM in age. The age of Stratum 2 alluvium ranges between ~32,000 and 41,000 yr and the age 
of the inset Stratum 3 sediment is between ~29,100 and 37,500 yr (Table 2). The ages appear 
to be reasonable given the estimated age of the stratigraphically older bajada surface (Middle 
Pleistocene) and the dating of the younger terminal Pleistocene fill (discussed below).

3.1.2 Stratum 4

Stratum 4 is topographically lower than Strata 1, 2, and 3, inset against the eroded toe 
of the bajada (Figures 4E). It consists of sandy and pebbly alluvium with more local clayey
facies. A strongly developed soil (Bt horizon with 7.5YR hues and thick, continuous clay films, and pervasive carbonate coatings on ped faces) formed through most of the stratum. Stratum 4 is most obvious on the south side of the site. It is found along the southwest margin of Locus 1 (Locus 1 South), at the foot of the scarp that leads up to the old bajada surface, exposed in BHT-6 (Figure 5) and in cores through the area (Figure S1). It is inferred to be present to the south in Locus 4 based on an exposure in the unnamed arroyo that separates Locus 1 from Locus 4.

In Locus 1 South the top of Stratum 4 forms a bench, likely an alluvial terrace, almost imperceptible topographically (Figure 5). This bench was initially recognized because of the dense concentration of coarse gravel at the surface along with a high concentration of lithic artifacts, including conjoining fragments of a probable Paleoindian projectile point and related artifacts. The layer of gravel with the artifacts rests on Stratum 4 and its associated soil.

The dating of Strata 2 and 3 suggests that Stratum 4 is <30k years old, assuming that the OSL dating in Locus 2 is accurate. Unweathered alluvium at the base of Stratum 4 (below the Stratum 4 soil) in BHT-6 yielded an OSL date of ~18,000 yr (Table 2). This date could be accurate or it is a minimum age. The degree of development of the soil formed in Stratum 4 suggests that the surface stabilized and then underwent pedogenesis for at least a few tens of thousands of years, based on dating of soils in similar settings across the Southwestern U.S. (Gile et al. 1981; Machette 1988; Birkeland 1999; Holliday 2004). Stratum 4 is also present near the north end of the site in Locus 3 and was exposed in BHT-4. At the base of the sequence in BHT-4 is a reddish sandy layer that yielded another OSL date of ~18,000 yr (Table 2). Soil development in
this deposit and the OSL dating at the base of the deposit indicate that this layer is equivalent to Stratum 4 in Locus 1 South. These dates suggest that there must have been an additional phase of local (if not regional) deep incision between ~30,800 and ~18,000 yr.

The gravel layer on the bench in Locus 1 South and resting on the Stratum 4 soil may be entirely redeposited from the adjacent scarp and bajada surface, but more likely the gravel was in place on the bench. The artifacts on that bench probably represent in situ occupation because the archaeological debris is continuous from Locus 1 South to and across Locus 1 North. Artifacts within the gravel may have been mixed in via bioturbation and soil shrink-swell.

3.2 Terminal Pleistocene and Holocene Deposits

The TPEH deposits at the Water Canyon site are the focus of our research. They contain the in situ archaeological record at the site. The deposits are divided into five stratigraphic units: four lithostratigraphic units (5, 6, 7, and 8) and one soil-stratigraphic unit (the La Jencia Soil). Facies of the strata are defined on the basis of lithological characteristics or color or both. Color variation includes post-depositional alteration, primarily by groundwater modification.

3.2.1 Stratum 5

Stratum 5 is a pebbly to gravelly to cobbly and locally sandy deposit that underlies Stratum 6 throughout much of the site. Data from Locus 1 suggest that Stratum 5 deposits are inset against Stratum 4 in a channel cut below Stratum 4 (Figure 4G). Exposures of Stratum 5
were limited to Unit 1-6 in Locus 1 and adjacent No Name Arroyo walls (Figure 3B), and in Unit 5-1 of the Locus 5 excavation block (Figure 6B). The coring rig rarely penetrated deeply into the gravel and, therefore, we could not determine the thickness of the deposit in most cores nor the character of it or its underlying deposits.

Stratum 5 is complex topographically, stratigraphically, and geochronologically. For example, where initially observed along No Name Arroyo (Units 1-6 and 1-5 in Locus 1 North), the top of Stratum 5 gravel is at 47.00 m and 47.03 m grid elevation, respectively. But 10 meters to the northeast, in the southwest corner of the deep Locus 5 excavation block (Unit 5-1), the top of the gravel is at 45.39 m grid elevation (Figures 6B, 7). Similarly, running from Locus 1 North to the east-southeast (based on coring) elevations for the contact between the top of Stratum 5 and the base of overlying Stratum 6 show a dramatic change in elevation of almost 4 meters (Figure 8). The mud of Stratum 6 engulfs the Stratum 5 gravel in some areas of the site (Locus 1: Cores 9-2, -6, -7, -10, -15, -18; Locus 3: Cores 10-15, -17; Locus 5: southwest corner of main pit and Core 10-10). In contrast, in BHT-4, cut across Locus 3, a time-stratigraphic valley-margin equivalent is composed of gravelly sand that is likely from slope wash based on thickening and facies changes toward the old bajada uplands (Figure 9).

The age and sequence of Stratum 5 deposition is difficult to interpret, limiting our understanding of the site formation processes. The estimated age range of the deposit can only be based on dates from above and below. As noted previously, the two OSL ages from the older (pre-TPEH) Stratum 4 deposits in Locus 1 (BHT-6; Figure 5; UNL-3856) and Locus 3 (BHT-4;
Figure 9; UNL-3859) provide an approximate minimum age for the base of Stratum 5 at ~18,000 yr (Table 2). The oldest radiocarbon age for overlying Stratum 6 is ~11,310 $^{14}$C yr BP (~13,170 cal yr BP).

As a whole, the paleo-topographic expression of Stratum 5 is that of an alluvial fan (Figure 4G). Elevations on top of Stratum 5 in and near Locus 1 and Locus 5 show that, at the mouth of the No Name Swale, Stratum 5 slopes down by several meters to the northeast across Locus 5 and to the southeast away from Locus 1; i.e., it has the shape of a fan with apex at the mouth of No Name Swale. The layer varies in content of sand, pebbles, and gravel, and degree of sorting from exposure to exposure. Alluvial fans are characterized by cut-and-fill cycles and that could account for the dramatic variability in lithology. Big Swale has a larger drainage area than No Name and likely contributed to deposition and erosion of Stratum 5. But very little of our stratigraphic or geochronological data can be directly linked to alluvial processes in Big Wash because very little late Quaternary fill is preserved there.

3.2.2 Stratum 6

Stratum 6 contains most of the archaeological remains recovered in situ at the Water Canyon site, primarily in Locus 1 North and Locus 5. It is up to ~200 cm thick and is primarily a dark gray to black mud, but there are several facies. Lighter gray and olive green facies are locally common as is an upland soil facies. In some areas of the site the mud encases underlying gravel, producing a mix (vertical facies) of Strata 5 and 6. Along the margins of the site there is
also an upland soil facies. Stratum 6 in at least one of its facies was found everywhere across the site except at the far east central portion of the site, east of Locus 1 and north of Locus 4 (Cores 10-23 to 29), due to erosion. One of the thickest and most complete sections of Stratum 6 is located in and just east of Locus 5. Stratum 6 rests unconformably on Stratum 5 and is locally inset against it or Stratum 4. Along No Name Arroyo and south across Locus 1, Stratum 6 is both atop and inset into Strata 4 and 5 (Figures 3B, 5, 7).

The dark gray-to-black mud facies of Stratum 6 with its distinctive color and presence of bone, is the most ubiquitous stratigraphic marker at the site (Figure 10). The dark color, fine-grained lithology, based on field texture and micromorphology (below and Supporting Information), and dating suggest slow aggradation of fines under conditions of high biological activity. The dark, subdued coloration and apparent biological activity tends to inhibit evidence for physical weathering such as root casts or cracking.

The olive green facies is a local biochemical alteration of Stratum 6. Where observed, the olive green facies is always below the black/dark gray facies and just above the gravel of Stratum 5 (Figure 10). The colors (gleyed or low chroma) are typical of reducing conditions in the presence of a high water table and abundant organic matter (Schaetzl and Thompson 2015: 483). The absence of mottled redoximorphic features (i.e., colors of both reduced and oxidized iron) are indicative of year-round saturation rather than seasonal water table fluctuation (Schaetzl and Thompson 2015: 356-358, 484). The gleyed facies is common only in the area of Locus 1 and to the southeast of Locus 1, but also minimally present far to the northeast along
Big Wash (section 12-9) and in an abandoned pit by an old windmill (Windmill Pit, Figure 2A). This patterning puts the gleyed facies in proximity to the older pre-TPH gravels and the bajada gravels, which, along with flow down the local drainages, could have been a source of seep or spring water that kept Stratum 6 saturated along the site margins.

The micromorphological analyses of thin sections collected in the Locus 1 excavation block provide some clues to the origin of Stratum 6 (Supporting Information). The thin sections (Figures S4-S11) show that there are subtle differences in the lithology of Stratum 6 in Locus 1, thus we subdivide it in Locality 1 into 6A and 6B. The lower part of the layer (6A) is finer (silt and clay), weakly laminated and pervasively gleyed. This suggests very low energy alluvial aggradation and perhaps additions of dust followed by reduction. Upper Stratum 6 (6B) is likewise dominated by fines and exhibits some weak bedding, but it contains some fine to medium gravel. The coarser particles are sub-rounded to angular, suggestive of short-distance transport.

Stratum 6B is mostly dark gray to black, but the micromorphology shows that the gleying characteristic of 6A also crossed the boundary between 6A and 6B and modified the lowermost portion of Stratum 6B. This discovery highlights the importance of differentiating facies based on sedimentological characteristics from those based on post-depositional characteristics. Stratum 6B exhibits localized gleying and some redoximorphic features, indicative of short-term saturation. The incomplete gleying and persistence of darker coloration is suggestive of either high original organic matter content or rapid burial shortly after
deposition of 6B. However, development of soil structure and coatings of illuvial clay in 6B demonstrate a period of subaerial weathering of 6B prior to burial. All thin sections also provide evidence of syndepositional or post-depositional bioturbation.

The gray facies is a deposit locally above and disconformably on the black/dark gray facies. It is common in the east-central area of the site, in and around Locus 5. The gray facies of Stratum 6 are sandy and locally pebbly near the site margins, probably picking up coarser clastics as slope wash. The upper gray mud also tends to be generally sandier. Influxes of sand (probably by both eolian and slope wash processes) would dilute the organic matter content and make the color lighter. The presence of oxidized iron staining (redoximorphic features) in the exposures of upper gray muds upstream of Locus 1 in the No Name Arroyo cut banks suggests the occurrence of seasonal water table fluctuations during the early Holocene.

A well-drained upland soil facies of Stratum 6 is located on topographically slightly higher settings in the north-central portion of the site (along the northeast edge of Locus 3) and on the bench along the southeast margin of Locus 1 South (Figures 9 and 5, respectively). This upland facies is a dark gray to black soil A-horizon. The sub-horizons of this soil (formed in Stratum 4; discussed above) vary from Bk horizons in sand to a clayey, well developed Bt horizon (Table 1; Figures 5 and 9). The topographic and stratigraphic facies relationships between the black mud facies and the soil facies show well at the south end of BHT-6 in Locus 1 where the soil is formed on two levels of the bench (Figure 5). Soil formation was on stable, slightly elevated landscapes roughly contemporaneous with aggradation of the other facies in
lower settings.

Stratum 6 apparently was subjected to several phases of erosion. This interpretation is based on the variable thickness of the layer, the abrupt and locally irregular contacts between Stratum 6 and overlying Stratum 7, the local presence of gravel lenses within Stratum 6 and on the Strata 6/7 contact, and radiocarbon dating. Otherwise, erosional contacts within Stratum 6 are difficult to identify due to the uniformly dark coloration which, as noted, obscures contacts such as erosional surfaces. In the exposure along the north side of No Name Arroyo, in the area of Locus 1 North and in the Locus 5 deep excavation block, at least one disconformity was observed within the gray facies of Stratum 6. More prominent is a disconformity at the top of Stratum 6 in Loci 1 and 5 and a disconformity cross-cutting Stratum 6 in the south and west walls of Locus 5. The latter erosion is due to the action of a re-routed paleo-arroyo (an earlier version of No Name Arroyo, discussed more fully below) that cut down through Stratum 6 and subsequently filled with Stratum 8.

The radiocarbon age estimates for the base of the Stratum 6 muds, either resting on top of the Stratum 5 gravel or encasing it, tend to be in the range of ~10,000 to ~9500 $^{14}$C yr BP (~11,450 to ~10,800 cal yr BP) across much of the site (Table 2). There are several significant exceptions to this trend, however. In Locus 1, on top of the Stratum 5 fan, the base of Stratum 6 yielded dates of 11,310 and 11,030 $^{14}$C yr BP (~13,170 and ~12,895 cal yr BP). Just northeast in the Locus 5 excavation block, lower Stratum 6 is dated 10,280 to 10,000 $^{14}$C yr BP (~12,005 and ~11,450 cal yr BP). Along the northeast margin of the site in or near Big Wash the base of
Stratum 6 dates to ~8810 $^{14}$C yr BP (~9820 cal yr BP). Further, dating and distribution of bone and lithic artifacts in Locus 1 North suggest an unconformity in the range of ~9200 to ~8300 $^{14}$C yr BP (~10,390 to ~9100 cal yr BP) (Figure 11). All of these ranges in radiocarbon ages suggest several episodes of significant erosion and incision. The earliest phase of erosion isolated, and left in place, a small pocket of Clovis-age muds in Locus 1 just beyond the mouth of No Name Swale and on top of the Stratum 5 fan. This erosion may have been between ~11,000 and ~10,360 $^{14}$C yr BP (~12,890 and ~12,240 cal yr BP) given the absence of dates in this age span across the remainder of site. Another cycle of erosion apparently was relatively widespread, given the extent of basal dates in the range of ~10,000 to ~9500 $^{14}$C yr BP (~11,450 to ~10,800 cal yr BP) across the site. The degree of erosion is highlighted by the topographically lowest component of Stratum 6 in Core 10-26, downstream (~130 meters) far to the east of Locus 1 and at grid elevation 41.8 m (compared to 47.0 m in Locus 1 and 46.2 m in core 9-10) (Figure 8). The base of Stratum 6 in that core dates to ~9745 $^{14}$C yr BP (~11,170 cal yr BP).

Sedimentation resumed, and then another phase of erosion ensued along Big Wash >8810 $^{14}$C yr BP (~9820 cal yr BP) and then along paleo-No Name Arroyo >8300 $^{14}$C yr BP (>9100 cal yr BP).

In Locus 5, the Stratum 6 black facies began to develop by ~10,280 $^{14}$C yr BP (~12,005 cal yr BP), which is older than some of the dating of the gleyed facies in Locus 1. The gleyed facies of Stratum 6 in Locus 1 and elsewhere in the site likely started as the black facies (the presence of abundant organic matter would help drive the gleying, as noted above). The process of gleying, therefore may have begun after ~10,280 $^{14}$C yr BP, but it is not isochronous across the
site. The gleyed facies at the base of Stratum 6 in Section 12-9 along Big Wash is dated to
\(^{14}\text{C}\) yr BP (~9820 cal yr BP), but the gleying could post-date the carbon that was dated.

The transition of the black facies to the gray facies is not well dated, but numerical age
estimates in Loci 1 and 5, and in Core 10-7 (Figures 2A, S1; Table 2), provide some clues. In
Locus 1, Unit 1-9, the upper black facies is dated to \(^{9310}\) \(^{14}\text{C}\) yr BP (~10,535 cal yr BP). A
concentration of charcoal fragments in the upper part of the gray facies, interpreted as hearth
Feature 1 (Unit 1-11), produced a mean date of \(^{8321}\) \(^{14}\text{C}\) yr BP (~9365 cal yr BP). In Locus 5,
charcoal from the upper black facies dated \(^{8775}\) \(^{14}\text{C}\) yr BP (~9755 cal yr BP) and charcoal from
the gray facies dated \(^{8395}\) \(^{14}\text{C}\) yr BP (~9400 cal yr BP). Similarly, just east of Locus 5 in Core
10-7, the transition occurred between \(^{8630}\) \(^{14}\text{C}\) yr BP (black facies) (~9660 cal yr BP) and
\(^{8305}\) \(^{14}\text{C}\) yr BP (gray facies) (~9280 cal yr BP).

This transition from black to gray is usually indicated by an abrupt contact and locally
accompanied by gravel, thus denoting some erosion. This likely explains some of the variable
dating among the three areas of the site. Erosion across the top of the black facies clearly
provides some variability. The timing of the black-to-gray transition could also be locally
variable across the site depending on influx of coarse clastics. The much younger ages for the
two facies on Core 10-7 may also be due to unknown contaminants.

The upper gray facies of Stratum 6 yielded broadly similar dates in Loci 1 and 5 and in
Core 10-7: \(^{8395}\) \(^{14}\text{C}\) yr BP (~9400 cal yr BP) in Locus 5; \(^{8321}\) \(^{14}\text{C}\) yr BP (~9365 cal yr BP) in
Locus 1; and \(^{8050}\) \(^{14}\text{C}\) yr BP (~8940 cal yr BP) in Core 10-7.
The age of the upland soil facies of Stratum 6 is, in part, a function of localized upland geomorphic processes. On the northeast side of Big Wash, in the Windmill Pit (Figure 2A), the upland soil facies yielded two dates of ~5600 $^{14}$C yr BP (~6385 cal yr BP) (upper) and ~6500 $^{14}$C yr BP (~7395 cal yr BP) (lower). Downstream from the Windmill Pit, approximately 320 meters along Big Wash (section 15-20, a black mud facies produced a date of ~6125 $^{14}$C yr BP (~7050 yr BP). This could indicate that the black, upland soil on the north side of Locus 3 is a facies of a younger version of the Stratum 6 black muds. Deposition of Stratum 6 spanned ~11,310 to ~8000 $^{14}$C yr BP (~13,170 to ~8900 cal yr BP). Breaks in the geochronology are indicative of erosion, in particular between ~11,030 and ~10,360 $^{14}$C yr BP (~12,895 and ~12,240 cal yr BP) and between ~9900 to ~9500 $^{14}$C yr BP (~11,310 and ~10,800 cal yr BP). These breaks and even erosion could also be due to drying conditions that precluded formation of a wetland.

### 3.2.3 Strata 7 and 8

Strata 7 and 8 are discussed together because of their similar lithologies and depositional environments. They are distinct stratigraphic entities, however. This inference is based on the presence of a mappable erosional disconformity between the two (Figure 6A). Both layers are sandy and gravelly, but fines are more common than in Strata 4 or 5 (Table 1). The exposures in the excavation block in Locus 5 show that Stratum 7 was deposited on top of the Stratum 6 gray facies following a phase of east-dipping erosion and gravel deposition across Stratum 6 (Figure 6A). A moderately well-developed soil formed in upper Stratum 7 where it is
unburied and in upper Stratum 8. The soil varies in thickness from 30 to >100 cm, depending on the thickness of the parent material (i.e., the thickness of Stratum 8 or unburied Stratum 7). It is usually a red Bt horizon that forms a distinct soil stratigraphic unit, here referred to as the La Jencia Soil. The degree of development of this soil was one of the stratigraphic characteristics that led to the realization that the black muds (Stratum 6) underlying Stratum 7 are of some antiquity.

The thickness of the combined Strata 7 and 8 decreases to the northeast, east, and southeast away and downstream from both Locus 1 and the mouth of No Name Arroyo (Figures 4I, 7). Similarly, the surface of these deposits (i.e., the present-day surface of the Water Canyon site) slopes down in the same directions, following the topography trending downslope with the present-day No Name Arroyo. These characteristics, together with the coarse nature of the sediments and the cut-and-fill stratigraphy, provide further indications that these strata comprise the upper portions of an alluvial fan at the mouth of No Name Swale.

Some cores revealed evidence of a buried soil (in the form of a Bw horizon or weakly expressed Bt horizon) in alluvium resting on Stratum 6 and, in turn, buried by younger alluvium, although this buried soil is not continuous across the site. In Locus 3 and Locus 1 South, the upland facies of Stratum 6 is locally, but not completely, buried by a layer of cobbles or by finer sediments with an A-Bt soil. The relative ubiquity and similar morphology of this covering soil, distributed discontinuously across the site, suggests that it is the same soil in each instance. As such, the alluvium in Loci 3 and 1 South most likely represents an eroded remnant of early
Strata 7/8. Further, the presence of at least one buried soil shows that Strata 7/8 aggraded episodically, at least in local settings.

An ancient channel of No Name Arroyo (referred to in this paper as paleo-No Name Arroyo) cut across the middle of the Water Canyon site, down through Stratum 7 and deep into Stratum 6. It was subsequently filled with Stratum 8. This paleo-arroyo was exposed in the southwest corner of the Locus 5 excavation block (Figures 6A, 6B) and can be traced upstream to the north wall of the present-day No Name Arroyo. The north wall of the paleo-arroyo was relatively steep (i.e., as exposed on the Locus 5 block) as was the lower half of the south wall of the paleo-arroyo as exposed in the modern No Name arroyo. But on the south side of the modern arroyo and in BHT-3, erosion by the upper half of the paleo-arroyo was more nearly horizontal, cutting across the top of the Stratum 6 black facies. Where it fills the paleo-arroyo, and prior to subsequent erosion, Stratum 8 is >3 m thick. Deposition of Stratum 8 was in at least two cycles, as indicated in the Locus 5 exposure (Figure 6A). The upper deposit of Stratum 8 thins to the south and is ~1 m thick as exposed in No Name Arroyo in Locus 1 (Figure 3B) and thins to less than 1 m further to the south (Figure 5).

There are no reliable dates directly from Stratum 7 in the areas of Locus 1 or Locus 5. It is younger than the Stratum 6 gray facies (<8050 ^14C yr BP; ~8940 cal yr BP) and older than Stratum 8, which is inset against it. The sheet of alluvium across the surface of Locus 3 produced an OSL age of ~8070 yr (Figure 9), further suggesting that it is a facies of Stratum 7. Stratum 8 produced a wide range of OSL dates and no radiocarbon dates. The OSL age
estimates range from ~9210 to ~8540 to ~6560 yr among the five dates from Locus 5 and one
date of ~9770 yr from BHT-3 in Locus 1 (Table 2). The sequence from Locus 5 comes from the
fill in the paleo-arroyo (precursor to No Name Arroyo) and also contains several reversals.
Given the upper radiocarbon age of <8050 ¹⁴C yr BP from upper Stratum 6, the three OSL dates
in the range of ~9770 to ~9020 yr (with large standard deviations) likely do not date the
deposition of Stratum 8. Given the short transport distances of sediments in the fan and
potential problems of OSL dating of alluvium (Walker 2005: 99; Bradley 2015: 97), partial
bleaching is a likely problem. The same problem could also apply to the date of ~8540 yr (R.
Goble, personal communication, Feb. 3, 2017). The two youngest OSL dates from the
sequence, ~6480 yr from the lower paleo-arroyo fill, and ~6560 yr from the top of Stratum 8,
appear to provide the best age estimates and suggest no significant break in time between
deposition of lower and upper Stratum 8.

4 ARCHAEOLOGICAL SUMMARY

After the site’s initial discovery, The Water Canyon site has been subjected to both
archaeological survey and excavation. The artifact assemblages in surface contexts at Loci 1, 2,
3, 4, and 6 were mapped and analyzed in the field. These assemblages included hundreds of
core flakes, biface thinning flakes, other debitage, projectile points, and tools. Fourteen
diagnostic projectile points and point fragments were collected from the surface and one
diagnostic projectile point was recovered from an in situ buried provenience (Table 3).
The faunal assemblage retrieved thus far from Locus 1 consists primarily of ~177 *Bison* sp. bone elements and bone fragments (of which 60 are identifiable to element), and tooth enamel pieces representing at least one bull, one to two cows, and three juveniles (Akins 2012; Dello-Russo et al. 2017). The horizontal extent of the Locus 1 faunal deposit is currently not completely defined and, although it may continue a little further to the east, no faunal remains were encountered in BHT-3, so it is likely that the majority of the assemblage has been recovered. Collagen samples from six elements have been radiocarbon dated and have returned ages ranging from ~9240 to ~8200 \(^{14}\text{C}\) yr BP (~10,390 to ~9150 cal yr BP) (Figure 11; Table 2), suggesting that the bone bed might represent the remains of at least two, and possibly three, chronologically separate events (Dello-Russo et al. in press).

Given these possibilities, a further exploration of the chronometrics in Locus 1 N is warranted. Three of the bone collagen radiocarbon dates from Locus 1 N (~9180 \(^{14}\text{C}\) yr BP, PSU-3564; ~9240, PSU-3565; ~9185; PSU-3566; Table 2) are from the lower bone cluster and they are statistically the same (Figure 11). These three collagen samples were subjected to ultra-filtration during pretreatment and their C/N ratios were each 2.8, indicating that the collagen in each sample was of sufficient quality to provide a reliable date. Their mean radiocarbon date (~9204 \(^{14}\text{C}\) yr BP ±30) is statistically different than that of the dated collagen sample in the upper portion of the bone bed (~8200, Beta 292053) (Figure 11). This suggests that the upper portion of the bone bed represents a later depositional event than the lower portion of the bone bed. It also suggests that the upper bone bed is similar, although statistically different, in
age to the Feature 1 hearth at a mean date of ~8321 (Figure 11). No C/N value is available for this upper bone collagen date, nor was the sample subjected to ultra-filtration during pretreatment, so it is likely that the date for this collagen sample is a little too young.

In addition, there are two other bone collagen dates in Locus 1 N (~8810, PSU-3567; ~8640, 16B/0713; Table 2) which, being only slightly different themselves (t=4.446), suggest a third possible bone cluster whose mean radiocarbon age (8682 ±35) is statistically different in age than both the lower bone bed and the upper bone bed (Figure 11). The collagen sample for the ~8810 date was subjected to ultra-filtration during pretreatment, while the collagen sample for the ~8640 date was not, so the latter date is probably a little too young. The three groupings of bone, artifacts, and charcoal illustrated in a back plot (Figure 11) present hypothesized temporal relationships of cultural materials and highlight the location of 1) the disconformities that we infer to exist between the upper and lower Bison sp. bone beds in Stratum 6 and 2) a possible disconformity between the western Bison sp. bone bed and the eastern Bison sp. bone cluster. Given the known potential for erosional unconformities in Locus 1 N, therefore, these dates and artifact groupings may reflect the processes involved in creating the cultural deposit.

Feature 1 in Locus 1 North (Figure 11) produced a dense concentration of charcoal fragments. Ten were identified as oak, pine, Ponderosa pine, juniper, and an unknown hardwood species (McBride 2012; Davis 2012). These 10 samples returned radiocarbon ages that are statistically similar (t=5.079) with a pooled mean ranging from ~8307 to ~8339 14C yr BP (~9113 to ~9525 cal yr BP). Only two of the charcoal dates fall within the range of ages
provided by the dated bone (~8160 to ~8240 $^{14}$C yr BP) in the upper portion of the bone bed. These charcoal fragments were also directly associated with burned and calcined bone fragments, and carbonized amaranth and goosefoot seeds. From these data, we infer the past presence of a small thermal feature or hearth (Buenger 2003; c.f. Surovell et al. 2016:83) spatially associated with the uppermost portion of the Locus 1 bone bed.

The lithic artifact assemblage recovered from Locus 1 North includes 141 unutilized debitage flakes, three retouched or utilized flakes, four bifaces, and four multipurpose tools, five scrapers, and two projectile point or hafted knife fragments, as well as a small, slab grinding / anvil implement. The types of artifacts in the assemblage, together with hearth charcoal, burned/calcined bone and a number of long bones that exhibited percussion marks, bone flakes and green-bone fracture edges comprise what we infer to be the remains of one, and possibly two, open-air activity areas utilized for bison processing during the Late Paleoindian (Allen-Frederick?) and the Cody (Eden) periods (Dello-Russo et al. in press). The affiliation of the upper open-air activity area with a possible Allen-Frederick occupation and the lower activity area with a possible Cody (Eden) era occupation are based on the probable dates of the bone beds themselves, at ~8200 $^{14}$C yr BP and ~9200 $^{14}$C yr BP, respectively. No temporally diagnostic artifacts were found in direct association with either of the bone beds.

The Locus 1 N Allen-Frederick era date conforms well with the 9350-7900 $^{14}$C yr BP range suggested by Pitblado (2003:112) for Allen-Frederick in the southern Rocky Mountains and the Locus 1 N Cody (Eden) date conforms well with the ~9800-8800 $^{14}$C yr BP range suggested by

An additional *Bison sp.* bone bed was discovered by mechanical coring in Locus 5, at approximately 3.5 m below the present-day ground surface in the black facies of Stratum 6. Directly associated with this deposit and recovered *in situ* in hand-excavated Unit 5-1, was the resharpened Eden projectile point. This is the only diagnostic artifact recovered from Locus 5, to date. Only 10 other lithic artifacts have been recovered from Stratum 6 in Locus 5 so far. We have also recovered, to date, more than 91 faunal elements, fragments, and tooth enamel pieces from the Locus 5 *Bison sp.* bone bed. These faunal elements recovered from Locus 5 represent an unknown number of individuals and their analyses are continuing. The bone bed is thought to cover more than 50 square meters and hand excavations in this area, thus far have only opened 10 one-by-one m units.

Determining the age of the *Bison sp.* bone bed and the associated Eden point in Locus 5 has proven problematic. Samples of bison bone and teeth yielded no collagen, thus far precluding the possibility of direct dating. When the feature was first encountered in core 10-1, Stratum 6 encased the bone. Two samples were collected and the SOM was dated (Figure 12; Table 2). The samples produced two dates between ~9887 and 9640 $^{14}$C yr BP (~11,305 and ~10,975 cal yr BP), from below and above the bone, respectively. These dates are stratigraphically correct and statistically different and could, thus, be accurate. Accordingly, the age of the encased bone could be the mean of these two dates, or ~9718 $^{14}$C yr BP. However, the difference in the dating could also be in part a matter of inter-laboratory variation (Taylor...
and Bar-Yosef 2014:147). Elsewhere in Locus 5, a similar SOM date of \( \sim 9750 ^{14} \text{C yr BP} \) (~11,180 cal yr BP) from a sample taken just below the bone bed in Unit 5-1 provided confirming evidence that the bone bed was no older than this and in the range of \( \sim 9718 \) to \( \sim 9750 ^{14} \text{C yr BP} \). This falls at the older end of the age range for Eden points as currently known for western North America (Knell and Muñiz, 2013:11-12).

Alternatively, the Locus 5 bone bed age might be indicated by an SOM date of \( \sim 8955 ^{14} \text{C yr BP} \) (~10,070 cal yr BP) determined on a sample collected near the Eden point found in the uppermost portion of the bone bed (Table 1) (Dello-Russo et al. in press). This date is well within the age range for Eden points on the northern and central Great Plains (Knell and Muñiz 2013:11-12) and within the range for Firstview points on the southern Great Plains (Holliday 2000). This leaves two scenarios for the age of the bone bed: the older dates could be due to mixing (from bison and human trampling during the kill and initial butchering and/or via bioturbation as the paleo-wetland evolved) or Eden occupations may be older in the Southwest than on the Great Plains.

5 DISCUSSION and CONCLUSIONS

The Water Canyon site is notable in the Southwest for its multiple Paleoindian occupations in an intact, stratified context (the only such documented Paleoindian site in New Mexico west of the Pecos River), its multiple *Bison* sp. bone beds, and its extensive paleo-wetland with abundant paleoclimatic and paleoenvironmental proxy data. The Water Canyon
site is also unusual in being one of the few Paleoindian sites preserved in an alluvial fan. The site formed at the mouths of several swales cut into the distal toe of the old bajada flanking the Magdalena Mountains and emptying into the Water Canyon drainage (Figure 4).

Archaeological materials are found at the surface on older, stable coalesced fan surfaces and on stable surfaces formed on Late Pleistocene sediments inset against those older fan surfaces. Buried, *in situ* cultural deposits are found in a paludal deposit that formed in the fans of intermittent drainages, here identified as No Name Arroyo and Big Wash.

**5.1 Soils and Geomorphology**

Incision of the main Water Canyon bajada (Stratum 1) likely began sometime before 42,000 years ago and the initial formation of the site landscape (cutting and filling associated with deposition of Strata 2 and 3) probably took place \( \approx 30,000 \) years ago (Figure 4). Deep incision then followed and there was at least one phase of alluvial deposition (Stratum 4) inset against the original Water Canyon bajada. This deposit is dated to \( \approx 18,000 \) yr, but soil development suggests that it could be older. It was incised and left as remnant benches in Locus 1 South and in Locus 3 (Figure 4). Stratum 5 alluvium is inset against Stratum 4.

Buried, *in situ* archaeological deposits are found in paludal mud (Stratum 6). The most common facies is black to very dark gray, but an underlying olive green or gleyed facies is present atop Stratum 5 gravels, and a lighter gray facies is on top of the black facies. The darker colors and fine-grained nature of much of Stratum 6 suggest the slow aggradation of fines, including alluvium and perhaps dust, under wetland conditions. The green coloration seen
locally in Stratum 6 is due to iron reduction (gleying) under conditions of a high water table and abundant organic matter. The gleying is likely post-depositional and, in at least Locus 1, was superimposed over at least one older disconformity within Stratum 6. The gleying is apparent along the southern flank and, to an extremely limited extent, along the northern flank of the site in proximity to the eroded margins of the bajada. The grayer facies is somewhat sandier than the black and green facies and likely represents a period of aggradation with more coarse alluvial and possibly eolian clastics, diluting the input of organic remains.

Stratum 6 does not represent uninterrupted sedimentation. Several disconformities are apparent. The oldest muds, dated ~11,310 to ~11,030 $^{14}$C yr BP (~13,170 to ~12,895 cal yr BP) and <~10,365 $^{14}$C yr BP (~12,240 cal yr BP), are in Locus 1, on a high bench of Stratum 5 gravel, and suggest several cycles of erosion just before and during the Younger Dryas Chronozone of the Terminal Pleistocene. Above those deposits are more Stratum 6 muds and sandy muds dated ~9750 to ~9200 $^{14}$C yr BP (~11,180 to ~10,390 cal yr BP) and to <~8321 $^{14}$C yr BP (~9365 cal yr BP). Elsewhere in the site, the oldest Stratum 6 deposits are slightly older than ~10,280 $^{14}$C yr BP (~12,005 cal yr BP) (Locus 5) and are on topographically lower Stratum 5 gravel. Thus, the oldest Stratum 6 deposits were removed from much of the site by erosion. In particular, Folsom-age (i.e., dating to the Younger Dryas Chronozone) and older deposits are largely missing with the exception of those on the high bench of Stratum 5 gravel. Mud deposition in Locus 5 then resumed after ~10,280 $^{14}$C yr BP (~12,005 cal yr BP) and continued until <~8395 $^{14}$C yr BP (~9400 cal yr BP). Away from Loci 1 and 5, another cycle of erosion was relatively
widespread, given the extent of basal dates in the range of ~9900 to ~9500 \(^{14}\)C yr BP (~11,310 and ~10,800 cal yr BP) across the site, i.e., there was erosion just prior to that time. The youngest deposit of Stratum 6 is the younger sandy gray facies, dated ~8395 to ~8050 \(^{14}\)C yr BP (~9400 to ~8940 cal yr BP). The top of Stratum 6 was heavily eroded <~8050 \(^{14}\)C yr BP, based on obvious disconformities in stratigraphic exposures and variable dating. The relatively long and continuous suite of dates for Stratum 6 from the Locus 5 area, beginning at ~10,280 \(^{14}\)C yr BP (~12,005 cal yr BP), suggests that this area of the site was spared significant early Holocene erosion, perhaps because of its position on a divide between No Name and Big Wash Arroyos.

The age range of Stratum 6 along Big Wash is significantly younger than it is on the fan emanating from the mouth of No Name arroyo. In section 12-9 on the south side of Big Wash, a base date is ~8810 \(^{14}\)C yr BP (~9820 cal yr BP). An upper black facies is dated <~8655 and >~7230 \(^{14}\)C yr BP (<9620 and >8065 cal yr BP). Above is a layer of dark gray mud dated to ~7230 \(^{14}\)C yr BP. Wetland conditions apparently persisted much longer (or are better preserved) along Big Wash. North of the wash in the Windmill Pit is an upland soil facies of Stratum 6 (with some gleying) dating from ~6500 to ~5600 \(^{14}\)C yr BP (~7395 to 6385 cal yr BP). The limited dating suggests that the paleo-wetland shifted north away from the No Name fan in the early Holocene. There are few dates along Big Wash because there are limited exposures. Moreover, there are no stratigraphic or geomorphic indicators of significant fan construction. This seems unusual given the much larger drainage area for Big Wash. But the swale that defines the wash (as opposed to the channel or arroyo) is also much wider (~82 m) just above the point at which
it widens at the site, compared to No Name Swale (~22 m) just above where it opens up. No Name Arroyo is in a position to create a fan, with flow confined to a relatively narrow swale until it reaches the end of the swale and water is no longer confined (a classic setting for a fan). The swale with Big Wash is wider and, as it gets into the site area, it becomes progressively wider. This geomorphic characteristic may have gradually dissipated discharge, rather than changing abruptly (as in the case of No Name Swale).

The characteristics of Stratum 6, as delineated previously, are indicative of a wetland and this interpretation is strongly supported by paleoenvironmental reconstructions based on proxy data recovered from Stratum 6 (Dello-Russo et al. 2016a, 2016b). These proxy data included stable carbon isotopes and other data derived from pollen (Smith 2010, 2012, 2015), land snails and snail eggs (Hall 2015), phytoliths (Yost 2016) and diatoms (Winsborough 2016). The Stratum 6 muds represent the remains of a TPEH wetland environment, characterized by wet meadows bordering a creek or interconnected pools and interspersed with marshy areas, similar to modern cienega ecosystems in the region. Taken as a whole, the record at the Water Canyon site indicates a landscape mosaic of different vegetation communities that, along with the presence of fresh water, would have provided a variety of shrubs, grasses and herbs strongly attractive to browsing bison and other game and non-game animals (Dello-Russo et al. 2016a).

The paleoenvironmental reconstruction suggests the presence of at least local shallow standing water. How this standing water was maintained is unclear. Today the site drainage
drops almost 20 meters over a distance of less than 1 kilometer to the confluence with the main channel of the Water Canyon channel itself. Stream flow is easy to maintain after rains. The coarse character of Stratum 5 and some of Strata 7 and 8 suggest flashy discharges from the No Name drainage and likely from Big Wash in the late Pleistocene and in the middle Holocene. Except for the evidence of erosion, Stratum 6, in striking contrast, is indicative of a high water table supporting a long-lasting wetland habitat.

Even with a high water table some sort of impoundment downstream from the Water Canyon site seems likely. The lower Big Wash drainage and, at its mouth, Water Canyon are both incised into either coarse gravel or bedrock so there are no clues to the terminal Pleistocene history of either drainage at their confluence. There is some evidence for mass movement along a bedrock slope failure on the south side of Water Canyon just downstream of its confluence with Big Wash (David Love, personal communication, 2009). Such a mass movement could have blocked the drainage and impounded stream flow, but that geologic record has not been investigated and, in any case, the mass movement is not dated.

Another possible mechanism for impounding the Big Wash drainage is the Water Canyon system itself. Aggradation of the drainage above, below, and at the confluence with Big Wash could have impounded flow in Big Wash and also could raise the local water table. Some fluctuations in the flow along Water Canyon could also account for the evidence of erosion in Stratum 6.

The Terminal Pleistocene stratigraphic record at Water Canyon contrasts with that from
other localities in the Southwest. The Mockingbird Gap site to the east-southeast (Holliday et al. 2009) and the Scholle site to the northeast (Hall et al. 2012) as well as Murray Springs and other Clovis sites in the upper San Pedro Valley of southeast Arizona (Haynes 2008; Haynes and Huckell 2007) all exhibit conformable stratigraphic sequences for the period ~13,500 to ~10,000 cal years. In particular, the Stratum 6 wetland mud is broadly similar lithologically and chronologically to that proposed for the “black mats” of the San Pedro Valley, the “wet meadow” zone at the Scholle site, and the palustrine muds (stratum 2) at the Mockingbird Gap site. But in detail, Stratum 6 is characterized by several cycles of erosion. Sediments of Younger Dryas age are largely missing and later phases of erosion are indicated between >~9500 \(^{14}C\) yr BP (>~10,800 cal yr BP) and >~8320 \(^{14}C\) yr BP (>~9365 cal yr BP). The Younger Dryas erosion may just represent local instability or may be indicative of regional variability at that time (e.g., Meltzer and Holliday 2010). Likewise, the early Holocene cycles of erosion have no direct correlates in the area (Onken 2015).

Strata 7 and 8 represent a return to more energetic cycles of fan deposition and erosion. They are sandier than Stratum 6 and both have common pockets and lenses of gravel. Stratum 7 rests unconformably on Stratum 6 and was truncated by erosion in the middle Holocene (Figure 4). Inset against Stratum 7 (on the north) and burying the eroded surface of Stratum 6 is more sand and gravel (Stratum 8). The erosion that truncated Stratum 7 also produced a deep paleo-arroyo (Figure 6A) that cut down through Stratum 7 and into Stratum 6 in a west-to-east direction across the middle of the site. Stratum 8, which filled the lower portion of the paleo-
gully, is dated to ~6500 yr. A well-expressed soil (A-Bt morphology; the La Jencia Soil) formed across the surface of the site in Strata 7 and 8.

The cutting and filling cycles of Strata 7 and 8 broadly mirror trends in the evolution of arroyos across the Southwest. Incision, fan construction, and another phase of incision are documented at Water Canyon between 6800 and 6200 yr. Localized and episodic but not necessarily synchronous incision is documented from ~8000 to ~5600 ¹⁴C yr BP (~8900 to ~6400 cal yr BP) across the Southwest (e.g., Waters and Haynes 2001; Mann and Meltzer 2007; Onken 2015) and attributed to the evolving Holocene climate, but the specific drivers are debated.

The gross sedimentological evolution of the landforms on which the Water Canyon site is located began with deposition of coarse, high energy, pre-LGM and LGM, Pleistocene gravel in an alluvial fan followed by erosion and then formation of a terminal Pleistocene/early Holocene wetland. Following another phase of erosion, thick sand and gravel deposits accumulated during cut and fill cycles as another fan formed. This stratigraphic trend is roughly similar to stratigraphic sequences across the Southwest and parts of the Great Plains (e.g., Holliday and Mandel 2006; Holliday and Miller 2013).

### 5.2 Archaeology

The Water Canyon archaeological site encompasses five different surface loci (1 South, 2, 3, 4 and 6) and two, possibly more, significant subsurface loci (1 North and 5). The subsurface cultural deposits are in fan sediments and consist of intact, buried Paleoindian materials in a stratified context. The fan contains several significant cultural deposits, including a bed of
poorly preserved *Bison sp.* bone with an associated Eden projectile point (Locus 5); and a possible palimpsest of two additional, but very well-preserved, *Bison sp.* bone beds with associated activity areas consisting of butchered bison bones, flaked and ground stone artifacts and the remains of an ephemeral hearth (Locus 1 North). The bone bed in Locus 5, associated with the Eden point, could be dated between ~9887 and ~9640 $^{14}$C yr (~11,305 and ~10,975 cal yr BP), although the projectile point itself is more closely associated with a date of ~8955 $^{14}$C yr BP (~10,070 cal yr). The upper portion of the bone processing area in Locus 1 North has a mean age estimate of ~8321 $^{14}$C yr BP (~9365 cal yr BP) (based on dated charcoal in the Feature 1 hearth), while the lower portion of that bone processing area is dated ~9240 $^{14}$C yr BP (based on dated bone collagen). The Locus 1 North bone bed is upslope of, and stratigraphically above, the Locus 5 bone bed. Clovis and Folsom occupations at the site are evidenced by diagnostic projectile point fragments documented in Loci 6 and 3, together with a suite of broken blade fragments repurposed into small, spurred end scrapers (Collins 1999) documented in Locus 6. Subsurface cultural deposits associated with these artifact types have not yet been identified at the site, although sediments dated to those respective time periods have been identified in Locus 1 North.

Buried, stratified Paleoindian sites are rare in southwestern North America west of the Pecos River. Between the Great Plains (northwest Texas/eastern New Mexico) to the east and the San Pedro Valley (Arizona) to the west, only two others are reasonably well-documented and both are in New Mexico: Boles Wells, a Folsom occupation in the Tularosa Basin just south
of Alamogordo (Mauldin and O’Leary 1994; Amick et al. 1996, 1998), and LA111429, a Folsom
camp site in the Jornada del Muerto, southeast of the town of Truth or Consequences (Figure
1) (Akins and Moore 2012: 82-98; Moore and Akins 2014). Sandia Cave (Figure 1) probably had
intact and stratified Paleoindian deposits, but they were obscured by animal burrowing
(Haynes and Agogino 1986) and the archaeological record was further mired in controversy
(Preston 1995). A buried Cody occupation may be preserved at the R-6 site near Las Vegas,
New Mexico (Figure 1) (Stanford and Patten 1984). None of the aforementioned sites west of
the Great Plains are securely dated nor are the stratigraphic contexts clear, however. So, the
lack of dateable Paleoindian deposits from buried, multi-component stratified contexts makes
the discoveries at the Water Canyon site all the more significant.

The Water Canyon site contains two Paleoindian bison bone beds (one of which is a
possible palimpsest of two distinct processing events and the second which is the remains of a
kill), another rarity west of the southern Great Plains in New Mexico and Arizona. Bison kills are
stereotypical characteristics of Paleoindian sites on the Southern Great Plains and across the
Southwest, expressed both as buried bone beds (Hester 1972; Johnson 1987; Jodry 1999;
Meltzer 2006; Haynes and Huckell 2007; Holliday et al. 2017) and surface assemblages of bison
tooth enamel or highly fragmented and desiccated bison skeletal elements (Beckett 1980;
Holliday et al. 2006, 2009; Huckell et al. 2008). The Water Canyon site is thus unique west of
the Pecos River in New Mexico for the reasons cited above and because it contains rare, intact,
open air processing areas.
6 SUMMARY

The Water Canyon site is a buried, multi-component, stratified Paleoindian site in the Southwestern United States. The archaeological materials are within an alluvial fan at the toe of a large bajada. It contains three late Paleoindian occupation features in ancient paludal deposits on and beneath coarser, higher energy deposits more typical of an alluvial fan. The oldest, well-dated occupation zone, at ~9240 $^{14}$C yr BP (~10,390 cal yr BP), is a bed of Bison sp. bones on the margin of the ancient wetland, interpreted as an open-air processing station. A nearby Bison sp. bone bed, farther out in the paleo-wetland and downslope from the processing station, and a probable kill site with an in situ Eden projectile point, currently dates to ~8955 $^{14}$C yr BP (~10,070 cal yr), but it may be older. It may be functionally related to the older processing area. The youngest, well-dated occupation level, at ~8321 $^{14}$C yr BP (~9365 cal yr BP), is also along the margins of the paleo-wetland and may also contain processed Bison sp. bone and a hearth. Both Clovis and Folsom artifacts have been found on the surface of the site, and remnants of both Clovis- and Folsom-aged paludal strata are preserved in the site but may be of limited extent. Nevertheless, the data show that the palustrine environment that interrupted fan construction attracted ancient foragers since at least ~11,000 $^{14}$C yr BP (late Clovis time) through the early Holocene.
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improved by a review from Lee Nordt and two anonymous reviewers.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

FIGURE CAPTIONS

Figure 1. Geographic setting of the Water Canyon site west of the Rio Grande in central New Mexico illustrating the general geomorphic features of the area (based on Machette 1988: figure 1). Inset shows the location of the figure area (dashed rectangle) in New Mexico along with archaeological sites mentioned in the text: BW = Boles Wells; C = Clovis (Blackwater Draw Locality 1); F = Folsom; LA = LA111429; R6 = R-6 site; S = Sandia Cave; SJ = San Jon; WM = Williamson-Plainview and Milnesand.

Figure 2. Topographic map of the Water Canyon site showing locations of: (A) Loci, soil sections, and lines of sections A-A’ (Figure 7) and B-B’ (Figure 8) and (B) excavation blocks and backhoe trenches (BHT). See Figure S1 for locations of all cores.

Figure 3. Views overlooking the Water Canyon site. (A) View to the north with excavations
under way in Locus 1. The area from the foreground north to Big Wash is the surface of the Terminal Pleistocene/Holocene fan encasing the buried archaeological materials, inset well below the surface of the Pleistocene bajada where Locus 6 is situated. (B) View east down No Name Arroyo at the head of the Terminal Pleistocene/Holocene fan showing the exposure of Strata 4, 6, and 8 (with 6 pinching out against 4) at section 10-30 with Locus 1N immediately beyond and the north end of BHT 6 (Figure 2B) visible at right center. Exposure of Unit 1-47 in Locus IN (Figure 2B) is on the opposite arroyo wall.

Figure 4. Late Pleistocene and early Holocene landscape evolution sequence. (A) Original Magdalena fan (bajada) surface on Stratum 1 at > 100 kya. (B) Paleo-channel incises Stratum 1 at >42.0k yr BP; Stratum 2 sediments fill paleo-channel at ~40.0k years BP. (C) Paleo-channel incises Stratum 2 at <40.0 kya; Stratum 3 sediments fill paleo-channel at ~30.0 kya. (D) Initial incision of Big Wash between ~30.8k and ~18.0k years BP. (E) Initial incision of No Name Arroyo at <18k years BP; Deposition of Stratum 4 at or <18.0k years BP. (F) Shallow bench cut on Stratum 4 then deep incision of Stratum 4 at <18.0k years BP. (G) Construction of Stratum 5 fan at <18.0k to >13.0k cal years BP. H) Paludal deposition of Stratum 6 at ~13.1k through ~ 8.0k cal years BP. (I) Deposition and erosion of Strata 7 and 8 from ~8.0k cal years BP to present.

Figure 5. Lithostratigraphy and soil stratigraphy exposed in a segment of Backhoe Trench 6 in Locus 1 (Figures 2B, 3B) illustrating position of OSL sample, erosion on Stratum 4, inset
relationship of Stratum 6 against Stratum 4, and facies relationship of Stratum 6 and its soil
facies. Secondary calcium carbonate is common throughout Strata 4 and 6 as films and threads.

Figure 6. (A) The west wall of the Locus 5 excavation block (Figure 2B) illustrating the
stratigraphic relationships of Strata 6 (black and gray facies), 7, and 8, and paleo-arroyo. (B)
Close-up of the excavations (Units 5-1, 5-6 and 5-8) and profile in the southwest corner of the
Locality 5 excavations (keyed to Figure 6A), illustrating the bottom of paleo-arroyo infilled with
laminated sediments of Stratum 8 and inset into Stratum 6, a portion of the *Bison sp.* bone bed
(Unit 5-8), and Stratum 5 cobbles beneath the black facies of Stratum 6.

Figure 7. Generalized stratigraphic sequence of the Water Canyon site along section A-A’
(Figure 2A) running northeast from Locus 1 South.

Figure 8. Generalized stratigraphic sequence of the Water Canyon site along section B-B’
running east-southeast from Locus 1 North (Figure 2A), illustrating the change in elevation
across the top of Strata 5 and 6. Radiocarbon means are provided for the base of Stratum 6 in
cores 9-10, 9-11, and 10-26 (Table 2).

Figure 9. Lithostratigraphy and soil stratigraphy exposed in Backhoe Trench 4 east of Locus 3
(Figure 2B) illustrating position of OSL samples, erosion on Stratum 4, and sloping fan-like
character and facies of Stratum 5. Secondary calcium carbonate is common throughout Stratum 5 and 6 as films and threads.

Figure 10. An example of the black and olive green (gleyed) facies of Stratum 6 along the North wall of Unit 1-47 on the north side of No Name Arroyo in Locus 1 North (Figures 2B, 3B). Cobbly Stratum 5 is overlain by the olive facies of Stratum 6 (6A) and, above, the black facies (6B). The dot on the aluminum can is the location for radiocarbon sample A-15021 (Table 2). It and the other sampling locations (dots) are labeled with their respective mean dates (Table 2).

Figure 11. West-to-east backplot of dated and undated bones, artifacts, and charcoal in Locus 1 North. Dates for bone collagen and Feature 1 hearth are in $^{14}$C yr BP (Table 2). Shaded areas illustrate inferred groupings of different age bone beds (upper and lower) and eastern-most bone cluster. Unshaded areas between bone beds/cluster represent inferred disconformities. The three bone collagen dates in the lower bone bed (bone cluster 2) are statistically the same (t=0.823) and their mean radiocarbon date is statistically different (t=26.765) than that of the bone collagen sample in the upper bone bed Bone cluster 1). The bone collagen date in the upper bone bed is statistically different than (t=7.466), but only slightly younger than, the Feature 1 hearth in the same bone bed. The third potential bone cluster, on the eastern side of Figure 11 (Bone cluster 3), has two dated bone collagen samples that are only slightly different in age (t=4.446) but whose mean date is very different than both the upper (t=82.239) and
lower (t=128.228) bone beds.

Figure 12. Bison bone found within the black facies of Stratum 6 in core 10-1 (Figure S1). The mud that encased the bone produced radiocarbon samples AA-95610 and Beta-317339 (Table 2).

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249x158mm (200 x 200 DPI)
Figure 12. Bison bone found within the black facies of Stratum 6 in core 10-1 (Figure S1). The mud that encased the bone produced radiocarbon samples AA-95610 and Beta-317339 (Table 2).