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Crossing the Jornada del Muerto: Hydrological and Geomorphological controls on traveling El Camino Real

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El Camino Real de Tierra Adentro, the 'Royal Road' from Mexico City to Santa Fe, was used for more than 300 years. Between the *parajes* (campsites) of San Diego and Fra Cristobal, the route leaves the Rio Grande valley and passes through the dry Jornada del Muerto. Water was an important consideration for travelers, both for themselves and their livestock. The present study was undertaken to identify and characterize hydrologic resources within the Jornada as they relate to travel along El Camino Real. In addition, we also mapped geomorphological landforms along the trail to help identify areas where water may have been available in the past and to assess geologic controls on the route established by trail.

Travelers

In historic accounts of traveling across the Jornada, group size and composition varies considerably. The smallest groups such as dispatch riders and merchants would consist of 10 people or less plus their mounts. Small scale commercial or military contingents, consisting of between 100 and 200 people with their mounts and carts, traversed the Jornada while on patrol, escorting official delegations, and delivering official supplies and reports. Large traveling groups often contained hundreds of people, dozens of carts and wagons, and hundreds of livestock. Finally, the largest traveling groups consisted of large herds of sheep being driven south to markets in Mexico. These herds routinely contained 2,000 to 5,000 animals, and herds of 30,000 sheep were not unheard of (see 'Water Requirement' table below).

Water Requirements

While precise numbers are hard to come by, water requirements for different sized groups can be estimated. Based on estimates of daily water requirements for people and different types of livestock, daily water requirements for the different groups range from approximately 135 gallons per day to 23,000 gallons per day for the small groups and largest groups respectively (see 'Water Requirement' table below).

Water sources within study area

Three primary sources of water were identified, including the perennial spring Ojo del Muerto in McRae Canyon, the cluster of playas near Engle, and intermittent seeps in Aleman and Yost Draws in the central portion of the study area. When these water resources are ranked by reliability and quantity, the most important source would have been the regional spring at Ojo del Muerto, followed by the playas near Engle, followed by water available in the seeps of Aleman and Yost Draws. Other streams in the area rarely contain water and were not considered further (see 'Ranking of Water Sources' below).

Landforms

Landforms along El Camino Real corridor and the Spaceport campus were mapped (see central map). The corridor runs parallel to Jornada Draw and includes a series of playas in the northern portion of the study area. The draw follows and is a consequence of the Jornada fault zone. West of this fault zone, bedrock is visible at the surface and groundwater is shallow. East of the fault, alluvial deposits are much thicker and groundwater is more than 200 feet below the surface.

Bedrock units (Tb, Rks, Rts, and Rtv) are found in the northern and west central portion of the corridor. Stable, relatively flat piedmont surfaces are dominant in the southern and east central portions of the corridor and extend to the north (Qf3, Qf2, Qp3, Qp2, Qf2, Qf1 and Qm1). These alluvial surfaces consist of pebbly sand and well developed calcium-carbonate horizons formed by episodes of deposition and stability during the Pleistocene (>12,000 years ago). Modern drainages are inset below the old surfaces and have low gradients (Qa, Qva, Qp4). Some exhibit episodes of arroyo cut-and-fill and may not have been entrenched when El Camino Real was first established.

When the route of El Camino Real is plotted, the trail crosses mostly dry, stable piedmont surfaces and avoids the potential muddy portions of the landscape along Jornada Draw (Qa, and Qp4). It is also worth noting that the trail appears to run from water source to water source, veering only to avoid potential muddy areas. Trail campsites, or *parajes*, are to be found near these same water sources. Together, these observations suggest that the route for El Camino Real was chosen based on the location of water sources, and for the most part crossed gentle hardpacked surfaces that could support large wagons, avoiding soft alluvium along drainages. (See Map)

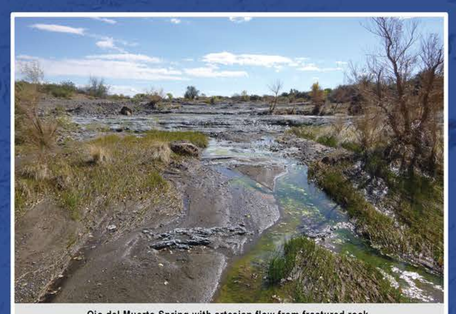
Conclusions

Ojo del Muerto spring was the key to travel across the Jornada. The spring has been reliable and produces a steady supply of good quality water. Near the midpoint in the Jornada crossing, travelers who reach the spring were guaranteed finding water to enable them to finish the remainder of the crossing. The playas also played an important role. When filled, they provided ample high quality water for even the largest of caravan or herd. Although these playas often dry out, as long as large caravans did not attempt the crossing until after heavy monsoon rainfall, those who reached the playas could water at this point and finish the remainder of the journey.

The seeps provide, at best, small amounts of water intermittently. The trail passes right by these sources, and they were undoubtedly used when available. However, their limited potential and intermittent nature suggests that they were probably viewed as an emergency supply.

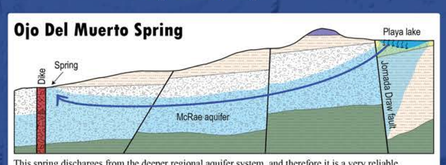
Appendices, references, and the GIS data for the landform units, and the poster are available for free download on geoinfo.nmt.edu/waterlamp/projects/El_Camino_Real.html

Funding for this project was provided by the New Mexico Spaceport Authority, per the mitigation plan for El Camino Real de Tierra Adentro.



Ojo del Muerto Spring with artesian flow from fractured rock.

Regional Spring



This spring discharges from the deeper regional aquifer system, and therefore it is a very reliable water source. There is evidence that this spring may have produced 16,000 to 25,000 gallons per day (Smith, 1893). This spring is located roughly at the half-way point along the journey through the Jornada del Muerto, and was likely the primary water source for most travelers. During the time when the Camino Real was being used, the Ojo del Muerto Spring was located approximately two miles to the west of the present location of the spring.

Broad swale of El Camino Real. Early mule drawn freight wagons were 12 ft (3.6 m) wide, producing a wide swale. Later carts and wagons were smaller, only 6 ft wide.

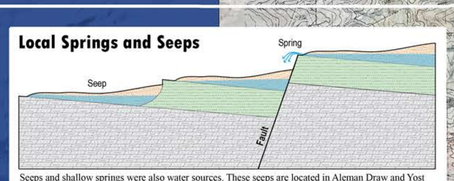
Hydrological Features

Playas Playa lakes, when filled, have the capacity to provision large groups and herds. However, the playas did not always contain water and did not fill every year. Even if there was a good monsoon there was no guarantee that the playas would have water, since the playas only flood as result of major storm events. We found that between September and October travelers would have had a ~35% chance of finding water in the playas. During the months of August, November and December the probability of water being present drops to 20%. In other words, on average, travelers would have found water in the playas every third to fifth year.

Calcium carbonate from shallow groundwater, near trestle, Aleman Draw.

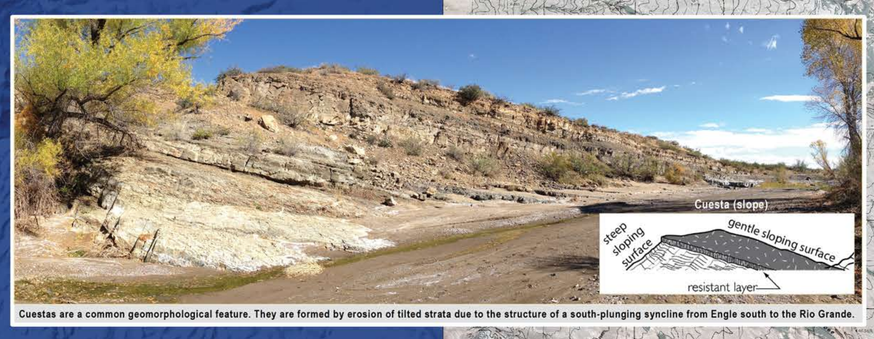
Local Springs and Seeps

Shallow groundwater seep in Aleman Draw.

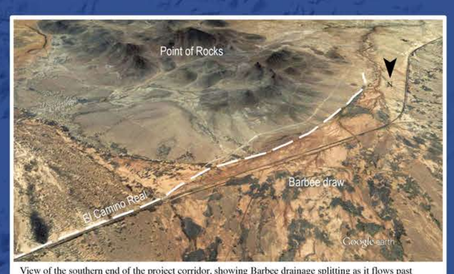


Seeps and shallow springs were also water sources. These seeps are located in Aleman Draw and Yost Draw and are characterized by moist sand and white precipitates on the bottom of the stream bed due to evaporation of shallow groundwater. When present, water at these seeps was easily accessible by digging less than a foot in loose sands and gravels. These areas where very shallow groundwater is observed are likely the result of subsurface bedrock forcing groundwater closer to the surface. It is likely that water from these sources was not available during years of drought.

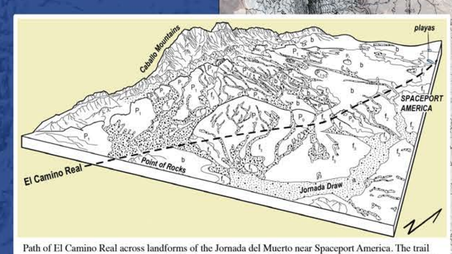
Geomorphological Features



Cuestas are a common geomorphological feature. They are formed by erosion of tilted strata due to the structure of a south-plunging syncline from Engle south to the Rio Grande.



View of the southern end of the project corridor, showing Barbee drainage splitting as it flows past Point of Rocks. Note that the Camino Real trail runs along the lower edge of Point of Rocks piedmont as far as possible, crossing the alluvium of Barbee drainage where the piedmont ends.



Path of El Camino Real across landforms of the Jornada del Muerto near Spaceport America. The trail crosses eroded, nearly planar bedrock (b), the lower margins of old piedmonts (P_0), old fan skirts (f_2, f_1), and minimizes the distance crossing the problematic active alluvium (a—Jornada Draw; at—tributary alluvium). The western edges of old piedmonts (P_0) are separated from their alluvial sources on the east side of the Caballo Mountains and are buried by inset fan skirts on their eastern margins. Younger piedmonts (P_1) are inset below the older piedmonts and are closer to their eroded mountain-flank sources.

This poster, OFR-574, is part of the Hydrogeology of the central Jornada del Muerto: Implications for travel along El Camino Real de Tierra Adentro, Sierra and Doña Ana County, New Mexico OFR-573, available online geoinfo.nmt.edu/water/amp/projects/El_Camino_Real.html

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Design by Brigitte Felix

AQUIFER MAPPING PROGRAM

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Water Availability and Implications for Travelers

Water Requirements by Group Size and Composition

Group size	# of people (1 gallon/person)	Large livestock (5 gallons per)	Small livestock (2 gallons per)	Total daily water needs
Large	500 (500)	500 (2,500)	10,000 (20,000)	23,000 gallons
Medium	250 (250)	300 (1,500)	1,000 (2,000)	3,750 gallons
Small	100 (100)	200 (1,000)	200 (400)	1,500 gallons
Micro	10 (10 gallons)	25 (125)	0 (0)	135 gallons

Ranking of the Water Sources

We ranked water sources in terms of reliability and quantity. Each water source was scored, with a higher score representing a higher rating. Reliability of a water source is a measure of the how it responds to short-term variability in precipitation. A highly reliable water source (high score) will provide a fairly constant volume of water, even during short periods of drought. An unreliable water source (low score) will tend to dry up or become inaccessible during periods of drought. We utilized simple mathematical models to assess the reliability of the different water sources. Ojo del Muerto spring is the most reliable water source, followed by the local springs and seeps, and the playas.

Quantity was assessed in terms of volume of water available. We estimated spring discharge rates and playa volumes and compared these estimates to projected water requirements for the different group sizes. Playas provide the greatest quantity of water and can easily support large groups that included hundreds of people and thousands of livestock. Ojo del Muerto spring was ranked second, while the local springs and seeps ranked last.

Reliability score (R)		
Regional spring (Ojo del Muerto)	Highest reliability	3
Local springs and seeps	High reliability	2
Playas	Intermediate reliability	1

Quantity score (Q)		
Playas	approx. +1,000,000 gallons	3
Regional spring (Ojo del Muerto)	approx. 15,000-25,000 gallons/day	2
Local springs and seeps	approx. 100 gallons/day	1

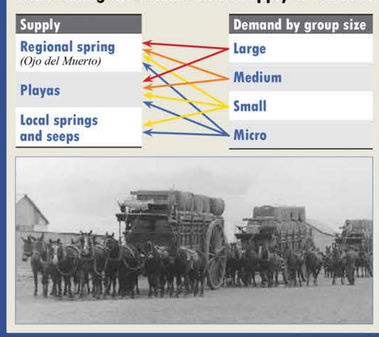
Water Source Evaluation: Reliability and Quantity

By adding reliability and quantity scores, the "best" water sources could be determined. Ojo del Muerto is identified as the "best" water source because of it high reliability and ample flow.

Water source	R	Q	Total
Regional spring (Ojo del Muerto)	3	2	5
Playas	1	3	4
Local springs and seeps	2	1	3

1. Ojo del Muerto regional spring
2. Playas
3. Local springs and seeps

Water along the Camino Real: Supply vs Demand



Correlation of Landform Units along El Camino Real, Jornada del Muerto Corridor, and Spaceport America

Post-bedrock units of McRae-Ojo del Muerto drainages
- Qva *Valley fill alluvium*
- Qvo *Valley margin alluvium*

Post-bedrock units of greater Jornada Draw

Alluvial units
- Qa *Axial stream floodplain and channels*
- Qap *Tributary valley inset alluvium*
- Qp4 *Young piedmont alluvium*

Playa units
- Ql *Playa*
- Qlf *Floodplain playa*
- Qla *Intermediate playa alluvium fill*
- Qlo *Old playa alluvium fill*
- Qle *Playa lunette*

Piedmont alluvial units
- Qf3 *Intermediate fan skirt*
- Qp3 *Intermediate piedmont*
- Qp3i *Intermediate inset piedmont*
- Qf2 *Old fan skirt*
- Qp2 *Old piedmont*
- Qm1 *La Mesa surface*
- Qf1 *Palomas fan skirt*
- Qp1a *Palomas piedmont*
- Qp1b *Camp Rice piedmont*

Bedrock units
- Tb *Volcanic edifice*
- Ti *Basalt dike*
- Rtv *Tertiary volcanic bedrock*
- Rts *Tertiary sedimentary bedrock*
- Rks *Cretaceous sedimentary bedrock*