BIGHORN GUZZLERS
IN
JOSHUA TREE NATIONAL PARK

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DRAFT
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INTRODUCTION

Since the 1950's, desert wildlife managers have installed and maintained artificial water catchments (guzzlers) with the intention of stabilizing and enhancing populations of game animals, particularly desert bighorn sheep and quail (Rosenstock et al. 1999). This policy has been very popular among hunting enthusiasts and the high price of bighorn hunting permits (currently auctioned at $100,000 and up) has funded the installation of hundreds if not thousands of guzzlers throughout the Southwest. Anecdotal reports and some studies claim increases in wildlife populations following guzzler installation (Bellantoni et al. 1993, Leslie and Douglas 1979) while others claim there is no evidence for such increases (Albert and Krausman 1993, Burkett and Thompson 1994, Campbell 1957, Krausman and Etchberger 1995). However, definitive evidence from rigorous scientific studies including pre-installation census data and environmental analysis does not yet exist (Rosenstock et al. 1999). Even after such studies are conducted, the results will certainly be controversial and may not be applicable to all wildlife or all wilderness habitats (Krausman and Czech 2000).

Some studies have pointed to negative side effects of guzzlers such as supporting a higher density of ravens that prey on tortoises (Knight et al. 1998); supporting more exotic bees that pollinate less native plants (Broyles 1995); harboring mosquitoes that may carry encephalitis (Hoff and Campbell 1957); and drowning of birds (Chilgren 1979), small mammals (personal observation), tortoises (Hoover 1995), and sheep. The most notorious guzzler fatalities occurred in the Mojave National Preserve in 1995 when bighorn lambs climbed on top of a fiberglass guzzler tank (see Russi's Rocks guzzler), fell in, and drowned. A total of 13 sheep drowned in the tank resulting in botulism contaminating the water and killing at least an additional 32 sheep (Swift et al. 2000). Fingers were pointed in many directions as the guzzler was not functioning properly at the time and no water was flowing to the drinker. Those with anti-guzzler leanings pointed out the dangers and failings of guzzlers. Those with pro-guzzler leanings pointed out the need for easy access and proper maintenance if guzzlers are expected to function.

Managers of desert ungulates cannot rely on the scientific literature for concrete answers regarding the policy of enhancing water availability (Krausman and Czech 1998.) The literature can, however, reveal the diversity of factors affecting the importance of water and demonstrates the complexities associated with water development. Because the results and side effects of guzzlers are rarely conclusive, the debate regarding the practice is often much more philosophical than scientific. Opinions vary widely on the interpretation of the Wilderness Act and the role of water as a limiting factor for desert wildlife. Some view the supplementation of water as a moral obligation to compensate for human impacts such as habitat fragmentation, draining of aquifers and even global warming. Aspects of this debate that will be explored in this document include legal concerns for habitat manipulation in wilderness, desert bighorn food and water requirements, history of Joshua Tree's water sources and guzzler program, drought patterns, and possible management alternatives.

WILDERNESS AND NPS POLICY

Joshua Tree National Park (JOTR) encompasses 792,000 acres, 583,000 of which are Federally Designated Wilderness with an additional 10,600 acres proposed and potential wilderness. The Wilderness Act of 1964 is of particular relevance as seven of Joshua Tree's guzzlers are in wilderness while the remaining three are in proposed or potential wilderness, which is also to be managed as wilderness (JOTR BCMP p. 28.)

> **Wilderness Act 1964, Definition of Wilderness, Section 4(c)**
> A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, <u>without permanent improvements</u> or human habitation, <u>which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable;</u>
>
> **Prohibition of Certain Uses, Section 4(c)**
> Except as specifically provided for in this Act, and subject to existing private rights, there shall be no commercial enterprise and no permanent road within any wilderness area designated by this Act and, <u>except as necessary to meet minimum requirements for the administration of the area for the purpose of this Act</u> (including measures required in emergencies involving the health and safety of persons within the area), <u>there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and **no structure or installation** within any such area.</u>

Artificial water sources, with pipes, tanks, aprons, etc. are certainly both structures and installations. Guzzlers require frequent inspections, maintenance and sometimes refilling, which can require motorized vehicles, equipment and even aircraft. However, an exception to the Wilderness Act may be made if guzzlers are deemed "necessary to meet the minimum requirements for the administration of the area." Effectively, if Joshua Tree's bighorn are currently dependent on guzzlers for survival, the guzzlers may remain in place.

National Park Service policy (NPS-77) states that "natural processes will be relied upon to control populations of native species to the greatest extent possible" and describes guzzlers as "habitat manipulation".

NPS-77 Native Animal Management (H, II, B) <u>Habitat Manipulation</u>
Habitat manipulation for management of native animals may be permitted when the manipulation is necessary to maintain or increase current numbers of a federally listed threatened or endangered animal species in accordance with approved recovery plans, or when the action, as documented in an approved resource management plan, <u>may help to prevent a species of concern from declining below a stable population.</u>

The desert bighorn sheep (*Ovis canadensis*) has never been state or federally listed as threatened or endangered. However, desert bighorn currently are a California "Fully Protected Species" (CDFG Code, Section 4700.) This status prohibits the take of bighorn unless a population has been thoroughly censused and evaluated as healthy, in which case hunting licenses can be made available on a limited basis (CDFG Code, Sections 4900-4904.)

NPS-77 defines a species of concern as "all native animal species within a park that face an immediate danger of losing their natural role in an ecosystem because of human-induced change." Although we have never had thorough census information for all of Joshua Tree's bighorn, estimates based on casual observations range from 150 to 200 animals for the entire park (McCutchen, pers. comm.) The Eagle Mountain population is our most thoroughly censused bighorn habitat and contains 68 $\pm$ 28 individuals (Divine 1996). It is the opinion of Joshua Tree's Chief of Resource Management that the size of Joshua Tree's bighorn population is stable and healthy under current conditions (McCutchen, pers. comm.) No obvious declines have been observed in comparison of visitor sighting records spanning the last 30 years. However, the "natural role" of the bighorn in the Mojave ecosystem is more ambiguous than simple population estimates.

Historically, desert bighorn ranged throughout the southwest states and Mexico from West Texas to California, and from Western Colorado, Utah and Nevada to Coahuila, Mexico (Monson and Sumner 1980). The current distribution of desert bighorn is sparsely scattered in isolated areas of the Southwest deserts where terrain is rocky, steep, and affords a high degree of visibility (Fig. 1) (Risenhoover and Bailey 1985, Trefethen 1975, Weaver 1985). While prehistoric numbers can only be guessed, the decline of bighorn sheep in North America since the arrival of Europeans is undoubted. Probably the greatest factor in the population decline of the desert bighorn has been the introduction of European domestic livestock and their associated diseases (Holechek et al. 1995, Valdez and Krausman 1999). Even today, grazing domestic livestock in bighorn habitat can mean numerous losses of bighorn to disease.

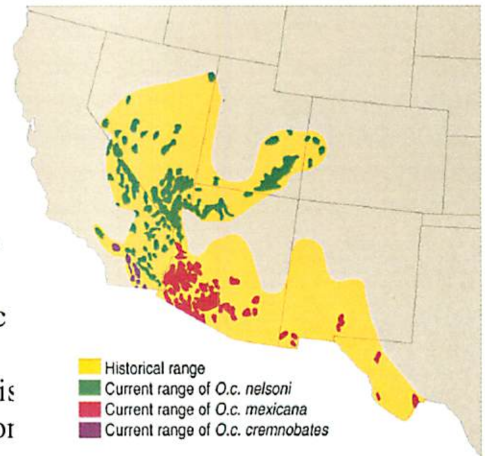

Figure 1. Historic range and current distribution of the three subspecies of desert bighorn in the Southwest U.S. (McCutchen 1995, redrawn from Trefethen 1975 and Weaver 1985).

In addition to direct mortality from disease, bighorn habitat has been fragmented and lost to roads, fences, canals, dams and cities. Bighorn are relatively intolerant of human disturbance and are impacted by many human activities such as mining (Leslie and Douglas 1979, Cunningham et al. 1993), recreation (Jorgensen 1974, Hamilton et al. 1982), construction (Krausman et al. 1979), and modification of water sources (Leslie and Douglas 1980). Due to the sensitivity of bighorn to disturbance, the zone of influence for these activities is considerably larger than the actual footprint of each activity (Ebert and Douglas 1993). Desert bighorn in Joshua Tree have certainly been impacted by mining and ranching activities in the past and recreation activities today although the effects of these impacts are not known.

The fragmentation of bighorn habitat and historic range may have affected or even impaired the desert bighorn's "natural role" throughout the entire southwest (McCutchen 1981). Individual populations no longer have the freedom of movement of prehistoric times to compensate for natural cycles of drought, drying springs and forage availability. It is not impossible that isolated prehistoric populations of bighorn may have periodically gone extinct due to climatic shifts, changes in water availability due to earthquakes, or even hunting pressures . In prehistoric times, animals would have freedom of movement between mountain ranges and thousands of years to return and repopulate areas after local extinctions. This is no longer possible without human intervention.

By all appearances, and despite fragmentation throughout the Mojave, Joshua Tree's desert bighorn are not in "immediate danger of losing their natural role" (NPS-77) within Joshua Tree boundaries; however, much more information on their population size, demography and habitat is needed to say for certain. It should also be noted that no other species, threatened, endangered, or otherwise is supplemented with anything in Joshua Tree National Park.

DESERT BIGHORN FORAGE AND WATER REQUIREMENTS

Controversy exists over the food and water requirements of desert bighorn and which one, if either, is the limiting factor in a given environment. Forage, water, and escape terrain are all crucial resources for desert bighorn survival (Risenhoover and Bailey 1985, Turner 1973, Krausman et al. 1989). Since escape terrain and forage appear to be plentiful in Joshua Tree, free water has long been assumed to be the limiting factor for Joshua Tree's desert bighorn population (Welles 1965). Although water is limited in desert environments, it is not necessarily the limiting factor for bighorn (Krausman and Leopold 1986).

Although desert bighorn will always drink water when it is available, sheep exist year round in mountain ranges without free standing water (Broyles and Cutler 1999, Krausman, et al. 1985). However, the hypothesis that bighorn can exist without permanent water is not widely accepted (Monson and Sumner 1980). J.C. Turner (1970) determined that desert bighorn need to drink a minimum of 4% of their body weight daily in order to maintain proper water balance. However, proper water balance and minimum requirements for survival are two different things. The frequency and amount of water desert bighorn require to survive is dependent on ambient temperature, number of days since last precipitation, and succulence of forage available (Campbell and Remington 1979, Turner 1970). Bighorn ewes were observed for ten day periods in July in the Harquahala Mountains of Arizona (Krausman et al 1985). Although temperatures exceeded 102° F during this period the ewes never drank free water, but were observed to break open and consume barrel cactus to obtain moisture.

2002 has widely been reported as the driest year on record in the California desert. In extremely dry conditions such as this, forage and even barrel cactus can also become dry and may not provide enough water for survival (Turner 1973). Free water may be critical during such droughts to carry bighorn through to the next precipitation. Ironically, it is just such critical times that guzzlers also fail. As of August 2002, many tanks, seeps and even dams have dried up in Joshua Tree National Park. A water source survey conducted in 2002 by Margaret Adam found a few scattered springs continued to provide ample water including Stubbe Springs, Pearl Spring, 49 Palms Oasis, Johnson Spring, Smithwater Canyon Spring(?), Munsen Canyon, and a few springs in Long Canyon. The guzzler survey conducted by the author found that in the Cottonwood area, Cottonwood Spring and a seep northeast of Lost Palms continues to provide water. All of Joshua Tree's guzzlers were dry from June to September 2002, with the exception of Russi's Rocks at the south end of the Coxcombs, which does not appear to receive any bighorn use. The Pine City guzzler refilled in September 2002 when a total of 0.14 inches of rain fell (measured at Lost Horse) on September 5 and 10, but the guzzler was dry again by early November.

The condition of Joshua Tree's bighorn observed in August 2002, was surprisingly good (Epps letter 2002). Eight sheep (4 rams, 2 ewes, 2 lambs) were seen at Stubbe Springs with sleek pelage and good musculature. Similar conditions were observed near Lost Palms where a group of 8 sheep (1 ram, 5 ewes, and 2 lambs) all in good condition apart from one old ewe with bleached and slightly shaggy fur. An additional ewe and lamb pair were observed at the same water hole that day. The ewe was in "fair" condition with prominent hip bones and a broken horn. All casual sightings in 2002 have reported healthy and even fat bighorn. In October 2002, 10 ewes from the Queen Mountain/ 49 Palms herd were captured, collared and evaluated by veterinarians. All ewes were fat, healthy, in excellent condition and abundant sheep sign was visible from the helicopter. Continuing observations of the collared animals will indicate the overall size and status of that population.

Of particular interest in Joshua Tree is the population of bighorn in the vicinity of Meek Seep in the north end of the Coxcomb Mountains. No sheep have been sighted this year but lamb and ewe pellets were found indicating a resident population of 10-15 animals (Epps letter 2002). Meek Seep was all but dry in August 2002. A very small amount of water may be available at dawn but no other available water sources are known in this area. Barrel cacti are available and may be supporting this population.

JOSHUA TREE'S GUZZLER PROGRAM

Data mining in the JOTR archives provided some historical background on the installation and maintenance of guzzlers in the park. However, some of the history can only be surmised as many key documents are missing. The following is as much history as could be gathered on JOTR guzzlers.

Joshua Tree's guzzler program officially began in 1960 with the installation of a French drain (buried perforated barrel to collect seeping ground water) and drinker at Dyke Spring, just above Lost Palms Oasis. At that time, Lost Palms had gone dry and no other water sources were known in the area. Ranger Robert Palmer located water four feet underground at Dyke Spring and installed a watering device, but by 1965 the device was already buried and clogged. Lost Palms remained dry for several years, at least until 1971 when the Dyke Spring drinker was rehabilitated with new concrete drinkers. As early as 1973 the guzzler was again buried by flash floods and by 1979, no monument personnel were even aware of its location.

In 1963, Weir and Bader wrote in their report on the Ground Water and Related Geology of JTNM, that water from Lost Palms was being "piped about 4 or 5 miles south for use outside the monument. The total quantity of water piped from the springs [was] no more than 2 gpm." Weir and Bader were probably referring to the water development at Chiriaco Summit which pumped water until sometime in the 1970's. Whether it was this pumping, below average rainfall or earthquake activity that caused the oasis to dry up is unknown. Moisture returned to Lost Palms Oasis presumably in the 1970's. As of August 2002 there is no free water available in the oasis itself, however, bighorn are watering at an active seep about 0.5 mile up canyon to the northwest.

The second guzzler installation was at Stubbe Springs in 1968 after numerous modifications to the spring failed to increase the amount of available water. Although the spring had flowed as much as 7 gph in 1961, it stopped flowing altogether in 1964 for unknown reasons. This unexpected drying may have been due to earthquake activity, human tampering with the spring, or prolonged drought in the 1950's and 1960's. It was also speculated that increased pumping of underground water in Morongo Valley may have lowered the water table to the point of drying historic springs in Joshua Tree (Douglas 1979).

Since the 1950's Stubbe Springs was known as the premier site for bighorn watching in the monument. Visitors, photographers and rangers were visiting the springs so frequently that bighorn became somewhat habituated and would drink within 30 feet of people (Inman report 1964). In the late 1950's and early 1960's bighorn were drinking from an increasingly deeper hole (2' deep x 2' wide), scooped out by well meaning rangers and visitors. Bighorn were forced to kneel and quail had to cling to the steep sides of the hole to drink water. The hole was continually filling with rocks and dirt from animal activity around and inside of it. In 1964 a major overhaul of the spring was conducted by Ranger Alsen Inman. The spring was excavated down to bedrock and cleaned of all clay and roots. A French drain was installed and drinker basins were constructed with stones and cement. A large willow tree above the spring was cut down and the roots were removed. Brush was cleared above the spring and the area was "naturalized" according to the 1964 report about the project. At the end of this project, the water was flowing approximately 3 gallons per hour. In 1965, the basins were dry (lower) and damp (upper) but flow (at an unknown location) was measured to be 1.15 gph. More brush (*Baccharis spp.*) was removed in an area around the spring approximately 150' by 80'.

The Stubbe Spring French drain system seems to have been problematic and must have been insufficient because a full fledged rain catchment guzzler was installed in 1968 in addition to the French drain. Unfortunately, due to below average precipitation, both systems were still insufficient for supplying bighorn with water. In 1970, the guzzler's collecting apron was expanded in the hopes of collecting more rainfall. However, no rain fell and the guzzler remained dry. In the fall of 1970 Dr. Roger Slocum visited Stubbe Springs and found it dry with the remains of three dead sheep and dead quail nearby which he assumed to have died of thirst. Too little remained of the dead sheep for an autopsy, so cause of death was in fact undetermined. Nevertheless, Dr. Slocum alerted reporters, the Desert Protective Council and the Humane Society, of the Park Service's supposed neglect. Dr. Slocum was only appeased when water was hauled out by tractor to the guzzler. In 1971, 1.5 miles of plastic pipe were installed along the trail so the guzzler could be filled remotely by water truck from the parking area on the service road. This remote filling was accomplished at least once before the spring started to flow again on its own.

In the 1980's the collecting apron at Stubbe was deemed unserviceable and was partially removed. The wooden support beams, guzzler tanks, pipes, drinker, drinker shade, cement basins, and French drain all remain on site with the natural spring flowing around them. Stubbe Springs should be analyzed by a hydrologist and should be restored, if possible, to natural conditions. Vegetation should not be removed on a large scale as it has in the past, but the willow tree might be replaced to provide shade for the spring and shade out some of the baccharis. The drinker on site is overflowing with water but is hidden in a cave of vegetation, covered by a collapsing plywood shade, and unavailable to bighorn or deer.

Around the same time the rain catchment guzzler was installed at Stubbe Springs, other guzzlers were installed at Pine Spring (near Pine City) and Rattlesnake Spring (on the west boundary of the park). Both of these locations are in close proximity to historic springs that have dwindled or dried. Bill Keys claimed that Pine Spring used to flow abundantly and called it a "heaven for quail and sheep." In 1944, flow from various outlets for this spring totalled 912 gallons per day. In 1948, only 47 gallons per day were flowing. This increased briefly in 1950 to 96 gpd but then quickly reduced to 10 gpd by 1952 and nothing by 1957 (from memorandum to Superintendent from Regional Research Biologist Lowell Sukner, 1958). 1946 to 1962 was a period of below average rainfall for Twentynine Palms that may have accounted for some springs drying (De Lisle 1999). However, 1976 to 1987 was an extremely wet period that may have recharged Stubbe Springs, but apparently did nothing for Pine City.

In 1971 a 14,000 gallon capacity adit was excavated in the north end of the Coxcomb Mountains, presumably by park staff. This horizontal tunnel was meant to be a catchment and storage tank for water running off the natural topography. The Coxcomb Adit has been problematic since the beginning. Dynamite used in the initial excavation fractured the rock walls, causing water to seep out. "Pour Stone" sealant was applied in the summer of 1986 and the fall of 1989 in an attempt to improve water retention in the adit. The leachbed/leachline collecting basin frequently fills with sand and requires shoveling out. Currently the adit is dry and contains the remains of a 5 year old ewe that may have died inside the adit. Cause of death is inconclusive as bighorn often seek a cool, shady place to lie in before death.

The last NPS installed guzzler was in Pushawalla Canyon near Pinyon Wells around 1977. The records and reasons for this installation are unfortunately lost, but the guzzler is currently dry and may or may not be functioning. All of the springs in the immediate vicinity of the guzzler are also dry. One letter was found relating to the installation of this guzzler from bighorn researcher Charles L. Douglas of UNLV. This letter expressed surprise at the sudden installation in what had been a "tentative site":

> "It was never my intention that the available guzzler should be installed at Pinyon Well – unless that location was shown to be suitable from the results of our study. This is reflected by Pinyon Wells being the number two priority in my earlier memo.... Needless to say, I was more than surprised when I learned, through John Cornely, that the guzzler was in the final stages of being installed." - C. Douglas 11/22/78

From 1977 to 1979 Charles Douglas conducted a study in the Stubbe Springs area, radio tracking bighorn ewes and rams to determine their range and optimum placement for the next guzzler (Douglas 1979). He found that bighorn watering at Stubbe ranged primarily to the south and west and recommended installing another guzzler about 1.5 miles southwest of Stubbe to increase the bighorns' range. Interestingly, in this report, Douglas enumerates the low success rate of Joshua Tree's guzzlers. "Two thirds of the water developments in the Monument have been of little or no use to bighorn sheep, for a variety of reasons." Douglas wrote that bighorn pass by but do not drink at the Pine Spring guzzler; there is no firm evidence sheep have used the Coxcomb Adit which had been plagued by maintenance problems since its construction; the Dyke Spring guzzler had been buried by flash floods and lost to Monument personnel; the Pinyon Well (Pushawalla) guzzler is not in an area of sheep use although it may be found by sheep that occasionally wander into the area. The only guzzlers Douglas did not criticize were Rattlesnake and Stubbe Springs.

In 1994, Joshua Tree inherited two bighorn guzzlers in the Coxcomb Mountains on land previously managed by BLM. The Coxcomb Guzzler (R-1), installed in the late 1950's by Richard Weaver for California Department of Fish and Game, is the oldest bighorn sheep guzzler in Joshua Tree and possibly the first guzzler installed in California. Inexplicably, this guzzler was placed in the center of a wide valley over 200 meters from escape terrain. When it was realized that bighorn would not risk crossing such open terrain for water, an additional drinker was installed near the rocks to the southeast with 1200 feet of extension pipe. Visits to this guzzler in 1968, 1986, 1996, and 2002 did not observe or record any bighorn activity or sign associated with this guzzler apart from a single track in the "wash above the black top" in 1986.

The newest guzzler in Joshua Tree is at the southern end of the Coxcomb mountains at Russi's Rocks. This guzzler was installed in 1984 presumably by California Fish and Game. Unfortunately, the park has records regarding its installation apart from a set of slides in the water source slide file. Both Russi's Rocks and the Coxcomb Guzzler were inherited by the park in 1994 when most of the Coxcomb Mountains were annexed by the park and declared wilderness. No sheep use at Russi's Rocks has ever been recorded. In August 2002 the guzzler was surprisingly full, containing about 2400 gallons. The water level had dropped only 200-400 gallons in four months indicating that water was lost mainly to evaporation rather than to wildlife. By September 4, 2002, the water level had dropped 200 gallons in only one month indicating more wildlife use. Very faint game trails can be seen leading up to the guzzler but no fresh scat was found nearby. A bighorn bedding area that contained 5 very old (at least one year, probably several years old) pellets was also identified in the canyon about 50 meters west of the guzzler.

A motion sensitive video camera was installed at the Russi's Rocks guzzler on August 7 and left for 28 days, during which there was no rainfall. The camera only functioned for one week before the battery cord was disconnected from the solar panel. During the time from August 7 to August 15 the camera was triggered several times and taped a fox drinking from the guzzler but did not record any bighorn sheep.

An even newer guzzler exists within park boundaries on an inholding belonging to R. Lane in Little Fargo Canyon. This guzzler was installed by Wildlife Unlimited in 1993, only one year before the JOTR boundary moved to include that area. This guzzler is well camouflaged to blend in with the surrounding rocks. It was also dry in April 2002 although it appeared functional. Bighorn had very recently passed by the guzzler and had consumed several barrel cacti in the canyon.

The two quail guzzlers are both located near the southern boundary, one in West Wide Canyon near Desert Hot Springs and the other in Pleasant Valley near Rock House Canyon. The West Wide guzzler could not be found in 2002 but was probably originally located on a Metropolitan Water District inholding. Consultation with Mike Meyer of the Palm Springs BLM office and Jim Cornett of the Palm Springs Desert Museum revealed that no one has seen any trace of the guzzler since 1971. Mike Meyer completed a guzzler survey of Riverside County in the 1990's and both he and Jim Cornett are familiar with the area. Neither the guzzler nor the road to it could be identified on an aerial photo of the area from 1970. This guzzler was most likely washed away in one of the massive flood events of the 1970's or 1980's. The other quail guzzler located near Rock House is in fragments and has not been functional since at least 1982. The Rock House guzzler was apparently installed on National Monument land, presumably by

California Department of Fish and Game, but all records regarding this installation are lost.

As of August 2002, all guzzlers within the park are dry, with the exception of Russi's Rocks, which is not currently used by bighorn, and Stubbe Springs, which is fed by natural spring flow and has a drinker inaccessible to bighorn. Earlier in the year, Rattlesnake and Pine Spring guzzlers both contained water and were receiving moderate to heavy use as evidenced by tracks and scat. The Coxcomb Guzzler, Russi's Rocks, and Pushawalla Guzzlers all showed little or no evidence of bighorn activity.

CLIMATE, DROUGHT AND PATTERNS

Almost all Joshua Tree documents regarding guzzlers claim persistent or increasing drought conditions (Welles 1965, Parry 1972, Douglas 1979). Drought is a normal, recurrent feature of climate, but is not easily defined (www.drought.unl.edu/whatis/what.htm). Drought varies from region to region, generally originating from a deficiency of precipitation over an extended period of time. Drought differs from aridity, which is a term restricted to regions of permanently low rainfall. In addition to low rainfall, conditions such as high temperature, high wind and low humidity can exacerbate drought.
The twentieth century saw a handful of major droughts in different regions of North America (www.ngdc.noaa.gov/paleo/drought/drght_temporal.html). The most famous of which is the Dust Bowl of the 1930's which was centered in the Great Plains and lasted for about 10 years. However, this was actually a relatively moist period for the Mojave. The second major drought occurred in the 1950's and was centered in West Texas and Oklahoma. This drought lasted for about 7 years and was also felt in Southern California. The third major drought occurred in the late 1980's and early 1990's and was centered around Oregon, Idaho, Northern California and Northern Nevada. This was also a comparatively moist period for Southern California, although Twentynine Palms received well below average rainfall between 1988 and 1990.

Drought can be measured by a number of drought indices measuring such factors as precipitation, humidity, snow pack and stream flow. The percent of normal is one of the simplest of these indices but can also be very misleading, since normal is a mathematical construct that does not necessarily correspond with what we expect the weather to be. Normal is usually determined as the average rainfall over at least 30 years and percent of normal is the fraction of rain received compared to that average or mean. This can also be manipulated based on the two time frames you are comparing. An extremely wet day, month, or even year, may not be enough to break a prolonged drought of several years.

Precipitation is highly variable throughout Joshua Tree. From the limited data available, it appears that precipitation in the park (from Lost Horse, Cap Rock, and Cottonwood rain gauges) usually exceeds Twentynine Palms precipitation but is roughly correlated to the same highs and lows (Fig. 2).

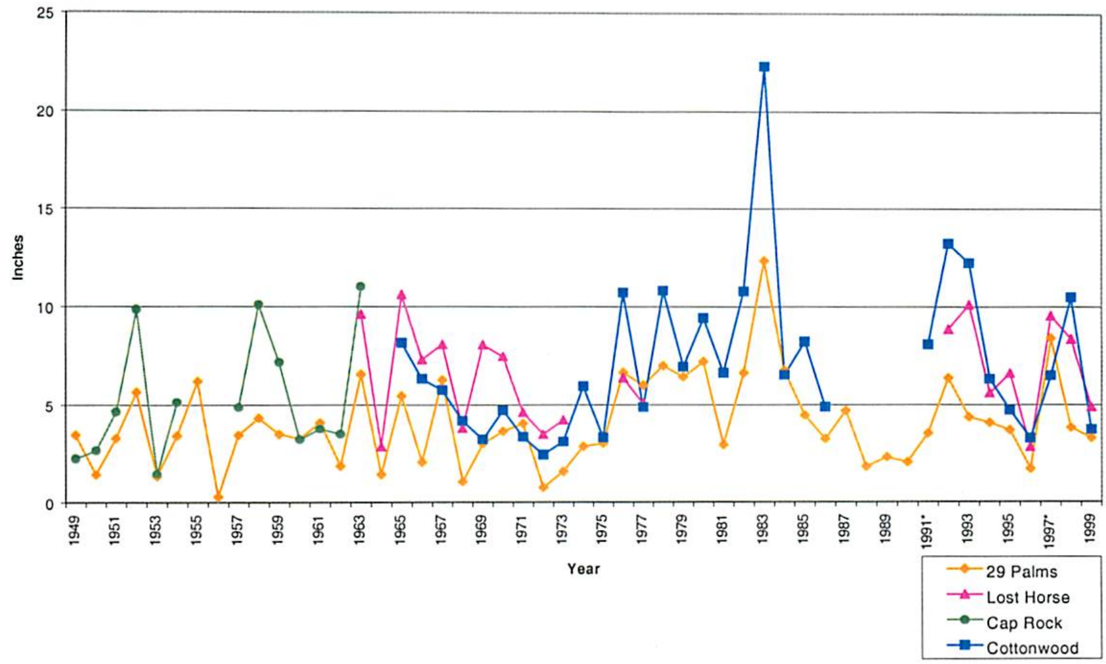

Figure 2. Comparison of Cap Rock, Lost Horse, Cottonwood and Twentynine Palms precipitation.

Because it is our most consistent set of data, and generally correlates with precipitation in the park, we will use Twentynine Palms precipitation as the measure for rain received in the park. Figure 3 shows precipitation data from Twentynine Palms since 1935 with the mean (Normal by definition above) in blue.

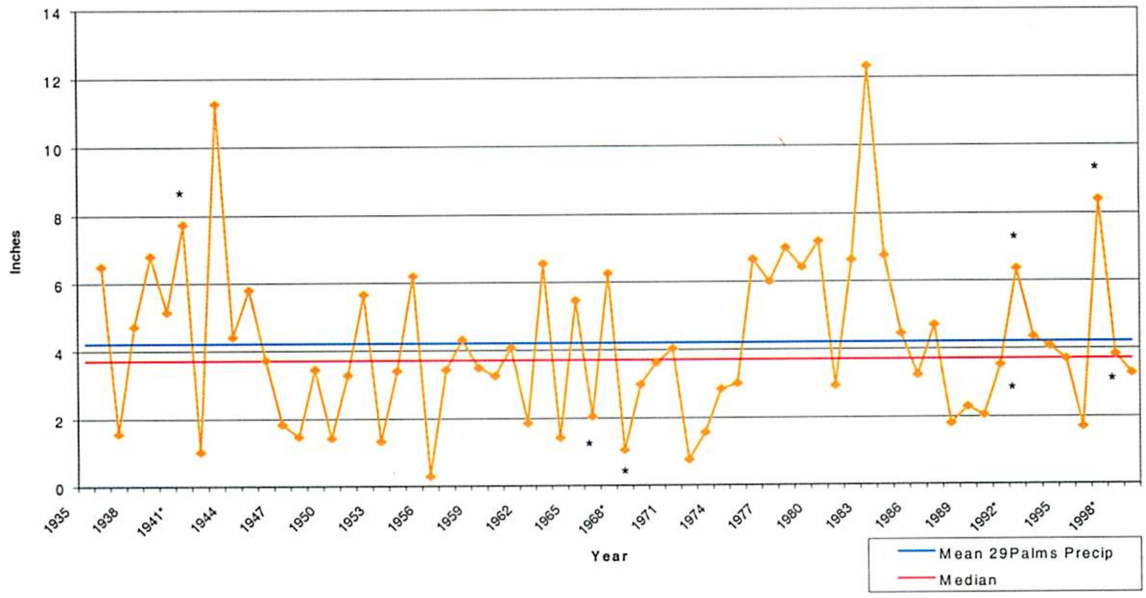

Figure 3. Twentynine Palms precipitation 1935-2000. * indicates incomplete data sets.

At first glance, it is difficult to discern a pattern in the above chart. However if the data is smoothed out a little by taking two year moving averages, a larger pattern emerges.

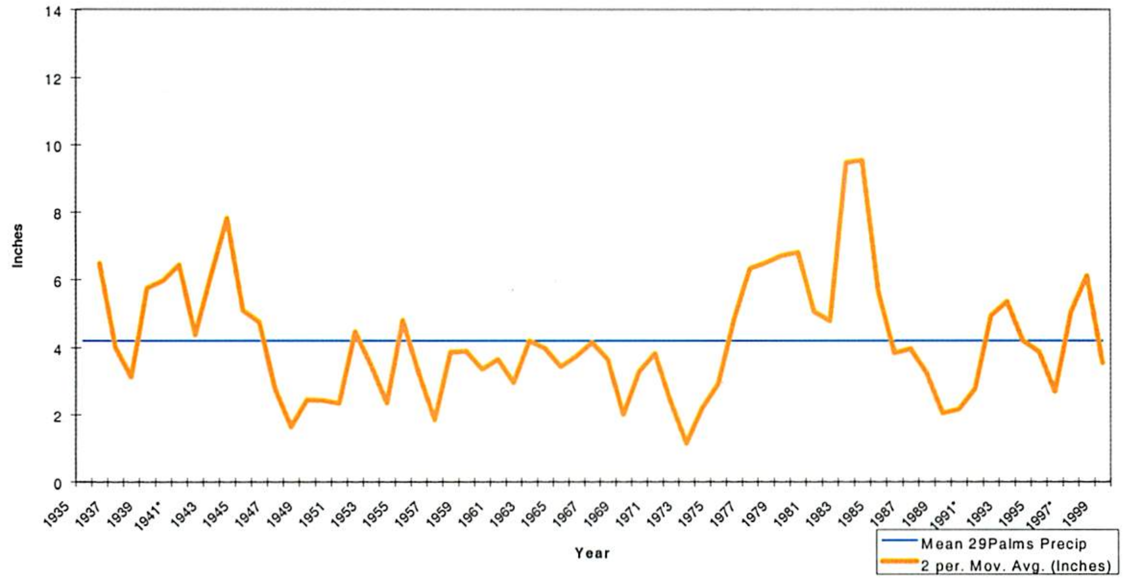

Figure 4. Twentynine Palms precipitation smoothed with a two year moving average.

Immediately apparent is a prolonged period of below average rainfall from about 1946 to 1976. This period was then followed by a very wet period from about 1977 to 1987 with wet spikes in the 1990's. This pattern becomes even more striking when it is compared to the pattern of Pacific Decadal Oscillation or PDO (Fig. 5).

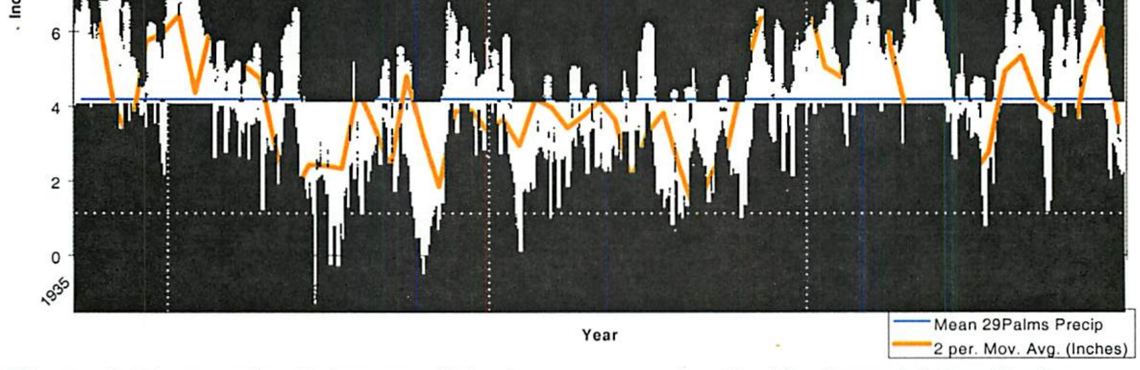

Figure 5. Twentynine Palms precipitation compared to Pacific Decadal Oscillation.

PDO is a long-term temperature shift in the Northern Pacific Ocean that can last for 20 to 30 years, compared to El Nino's 6 to 18 months. No one knows what causes this temperature change but the correlation between PDO and precipitation has been observed by many climatologists (http://tao.atmos.washington.edu/pdo/). Since we only have records for the last hundred years, we do not have enough data at this point to say this is a regular, predictable cycle of wet and dry periods. However, if it is, we are currently headed into a downward swing in the cycle that could mean another 20 to 30 years of below average precipitation, similar to the 1950's and 1960's (Hereford 2002).

Regardless of whether PDO is predictable or not, the droughts of the twentieth century were fleeting in comparison with droughts that have occurred in the last 2000 years. Tree ring data indicate that long term droughts of 20 to 30 years duration occurred around 1675 and 1300 and earlier (Grissino-Mayer 1996, Hughes and Graumlich 1996, Stahle et al. 2000).). In California, fossil pollen, sedimentary layers, archeological sites and tree ring data all provide evidence for two massive, epic droughts of 140 and 220 years between the 9th and14th centuries (Boxt 1999, Stine 1994). Even if there is no predictable drought cycle, it seems we may be due for another "epic drought."
What this means for Joshua Tree's guzzler policy is difficult to say. Desert bighorn have certainly been exposed to "megadroughts" far worse than we know of in past millennia and obviously survived. Whether or not these droughts were accompanied by massive die offs that the bighorn only barely survived may be determined by ongoing genetic research. It is possible that in the past, isolated populations of bighorn may have died off entirely, but given 1000 years and freedom of movement between mountain ranges bighorn would slowly repopulate the available habitat. In our modern, fragmented desert this is no longer possible. Current genetic research done by Clint Epps at UC Berkeley, may help to understand the relationships and possibly the history of desert bighorn in the Mojave. By sampling genetic material in bighorn pellets from all the mountain ranges in the Mojave, Epps will be able to determine how the isolated populations are related and approximately how long they have been separated. If there is no evidence of population extinctions in the DNA, then we will have a better estimation of how well bighorn can survive extreme drought. If, however, the DNA shows that modern populations are closely related and local extinctions have been frequent, then we will probably want to take more aggressive steps in ensuring the survival of Joshua Tree's bighorn.

At this point it is particularly interesting to note that while the United States has been involved in an aggressive water development program for the last 50 years, Mexico's desert sheep population seems to be doing exceedingly well without such a program (Lee 1993).

JOTR GROUND WATER

One of the most important issues in the management of Joshua Tree is also one of the least understood. Several of Joshua Tree's historic springs have gone dry in recent decades: Pine Spring, Stubbe Springs, Quail Springs, Lost Palms. Other wells have measured decreasing water levels although it is uncertain how regular and consistent the measurements have been. A two year ground water study from 1974 to 1976 found a slight overall decline in water levels in Joshua Tree although some levels rose and some stayed the same (Downing 1977, 1978.) The most dramatic decline was a drop of 3 feet in Willets Well (near Samuelsen's Rocks), which had shown a steady decline of 45 feet since 1966. The author of that report hypothesized that the drop was probably caused by Barker Dam blocking surface runoff about 6 miles upstream.

Many NPS memos found in the JOTR archives theorize that the drying of springs is due to increasing drought, ground water pumping outside the park, or earthquake activity. No one appears to have the answer at this time. If Joshua Tree is to make management decisions based on the availability of natural springs and ground water, a large scale hydological study should be undertaken to answer these questions.

MANAGEMENT ALTERNATIVES

At this time there are three or four guzzlers (or guzzler remains) that are obvious candidates for removal. The Dyke Spring guzzler and Rockhouse (B-36) quail guzzler are little more than hunks of concrete in wilderness. The Dyke Spring guzzler requires particular attention as it is located in the center of a palm oasis that would certainly benefit from the removal of this concrete and subsequent revegetation. The Coxcomb guzzler was poorly designed, is badly eroded, located in the wrong terrain, and contains asbestos sealant. This guzzler should be removed but will require testing of the asbestos material and possibly hazardous material procedures. The placement of the Pushawalla (Pinyon Wells) guzzler seems to have been inadvisable from the start as it is outside of any known bighorn habitat. This guzzler also needs further investigation to determine its functionality. Stubbe Springs requires the consultation of a hydrologist to determine if the French drain and guzzler tanks should be left in place or removed.

Pine City, Rattlesnake, and Russi's Rocks all require further investigation regarding bighorn use and dependence. Pine City and Rattlesnake might benefit from maintenance such as sealing the inside of the storage tanks or total redesign to improve reliability.

Whatever the eventual scientific verdict, providing one can be found, each guzzler will have to be dealt with on a case by case basis. The following is a complete inventory of all Joshua Tree guzzlers with maps, photos and documents from the archives.

The most obvious negative aspect to guzzlers is that they are unreliable and inadequate. It is precisely when guzzlers are most needed that they are empty. If a guzzler program is to be continued in Joshua Tree, it would require much more active maintenance, monitoring, filling and possibly redesign and renovation of the existing guzzlers.

More conclusive studies on bighorn and desert mule deer with pre- and post-guzzler data comparisons are underway, but years from results. Results from Epps' genetic study mentioned above are still one to two years off. It would be advisable to delay action on the functioning guzzlers until more scientific evidence is available.

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