# JUSTIFICATION FOR THE CONTINUED USE OF WILDLIFE WATER DEVELOPMENTS FOR THE MANAGEMENT OF BIGHORN SHEEP POPULATIONS IN THE SOUTHWEST UNITED STATES

Prepared for:

Arizona Desert Bighorn Sheep Society

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## ABSTRACT

It is the purpose of this paper to assist current and future natural resource managers to make the best decision possible when considering water sources for desert bighorn sheep. It can serve as a resource when managers are requested to justify the decision.

The idea that large herbivorous mammals are able to persist in the American deserts without access to free water has been speculated upon for nearly 100 years. This idea was speculative then, and it remains largely so today. This paper describes much of the history and development of this idea.

Numerous scientific investigations have been completed that are directly related to this issue; some make a strong case to support wildlife water development, some claim to challenge the concept. This paper evaluates key research that buttresses the primary arguments and concludes there is an overwhelming combination of evidence and logic that affirm this management strategy. The evolutionary argument that natural behavior is adaptive requires contemporary biologists to interpret the seasonal behavior of desert bighorn sheep at water sources to be adaptive.

There is a perceived need to choose either classic Conservation Biology or an Ecosystem Management-based resource management prescription. This paper examines this apparent schism further and concludes there is no real contradiction of either school of thought when deploying wildlife water development strategies.

I describe a philosophical and scientific basis for wildlife water development and enhancement activities. I discuss this management activity as being within the rightful jurisdiction of the state to manage its resident, non-threatened wildlife.

This paper discusses a number of case histories that provide cumulative evidence over time, that desert bighorn depend on water sources to complete their life cycle and maintain thriving populations.

It concludes with a number of management recommendations.

KEY WORDS Wildlife Water Development, bighorn sheep, Ovis canadensis

## ABOUT THE AUTHOR

John Gunn is a retired Arizona Game and Fish Department Wildlife Specialist. He has worked with desert bighorn sheep, particularly with issues related to wildlife water development, evaluation, and assessment throughout a 20-year career. He has authored two previous publications on the subject of water developments (Gunn 1988, 1998).

## INTRODUCTION

The argument that desert ungulates, particularly bighorn sheep (Ovis canadensis) do not require free water, and therefore "artificial water" should not be provided for them, is not supported by a credible body of evidence, and indeed is largely a philosophical rather than scientific challenge. It is a challenge that is readily countered by understanding the ecological implications of these animals' behavior around water sources. Numerous grey literature as well as extensive scientific studies, including quantified bighorn population responses, adequately refute the fundamental challenge; that thriving populations of desert bighorn sheep can persist over time in the absence of reliable water sources. Recent documented cases of water development failures with attendant loss of bighorns provide strong evidence that desert bighorn require drinking water to complete their life cycle. Even in the comparatively ancient old world deserts, very few species of a much richer ungulate fauna have evolved to become actually independent of surface water. Therefore we should not expect it this soon in the new world and in the genus Ovis - a genus that has largely evolved in association with alpine environments and that also exists in the old world and has not achieved independence from water there, either.

Desert bighorn sheep are still biologically threatened; they are in short supply, and occupy only a small portion of their original distribution. They are a species sensitive to several degrading human activities. Their presence increases the value society places on the public lands they inhabit. With past and ongoing human induced degradation of southwestern deserts, and the subsequent decimation of this subspecies, it is not appropriate that public resource managers merely allow desert bighorn to persist at densities that invite extirpation. A manager's public trust is to insure these and other wildlife resources thrive in those remaining areas where this is still possible.

It is somewhat unique in the arena of natural resource management that the decision to implement, or redevelop an existing wildlife water development, is a readily reversible one. In contrast, the decision to do nothing, or to respond inadequately, has likely ramifications that will reduce the diversity of the local gene pool and a commensurate loss of the aggregate social knowledge of a particular bighorn herd unit. Once lost, these assets to the population are difficult, perhaps impossible, to recover.

Arizona's desert bighorn sheep population has increased 25% in one decade from an estimate of 4500 in 1988 to around 6000 in 1998 (Lee 1998). Nevada has experienced a similar rate of increase. The coordinated modern management approach of providing and maintaining water sources, translocating new herds, partnerships with private groups, and inter-agency collaboration that consider bighorn needs during the habitat management planning process have accomplished this. We are still working towards the objectives identified in the Arizona Bighorn Strategic Plan (AGFD 1995). There is no compelling argument nor data set to indicate a need to change our management direction. While we have been clearly moving in the right direction, with most herd units still numbering less than 100 individuals, and approximately 15000 sq. km (9900 sq. mi) of bighorn habitat in Arizona, there is still much work to be done.

The direction this controversy has taken thus far, and might take in the future, has a direct impact on the authority and decision ownership regarding which and whose management philosophy ought to be applied to bighorn sheep populations located on public lands.

The states have the right to manage their own non-listed (Threatened or Endangered), non-migratory wildlife. The southwestern state wildlife agencies have a public duty, mandated by their Mission Statements and various species strategic plans, to continue to bolster their desert bighorn sheep populations.
Federal land managing agencies have a commensurate duty to cooperate with the state and facilitate them in meeting these obligations (BLM 1995). As the best remaining desert bighorn habitat has recently been designated wilderness, it is requisite to the continued recovery of desert bighorn sheep that management activities be permitted in these areas.

I have seen this controversy grow and the challenge to this management strategy gain wider acceptance over the past decade. I have noted that opposition to wildlife water developments arises from several viewpoints. Many, perhaps most, start from a paradigm that man has "screwed up" nature bad enough, that remaining areas should be managed as they are or - even better - as a preserve or wilderness. Implicit with this viewpoint is the idea that we do not have enough knowledge to "improve upon nature", and that nature should "be allowed to take its course". It is often argued that only ecosystems should be managed, not single species such as bighorn sheep. Some have published professional papers stating that until the benefits to wildlife have been more clearly demonstrated, the activity should be curtailed.

I have seen this controversy about "providing artificial water" grow and gain wider acceptance by biologists, wilderness specialists, and other resource managers over the years. The increasing acceptance of this challenge is the reason I requested the Arizona Desert Bighorn Sheep Society to support the production of this paper, which extols the philosophical and scientific basis for continuing this management activity.

I have been fortunate enough to have had the opportunity to work with and discuss desert bighorn sheep management with a wide range of Southwestern biologists and naturalists for many years. I have observed a great number of bighorn and other wildlife waters, natural and manmade, functioning in a wide variety of range sites throughout much of the Southwest and Sonora. I have also observed bighorn occurrence and population trends in a number of areas where there is minimal perennial water such as the Ajo Mountains in Organ Pipe Cactus National Monument. I am familiar with the response (generally no bighorn present) in areas that are largely devoid of reliable water sources, examples being otherwise suitable mountains in NW Sonora, on the Tohono O'odham Indian Nation (Brown 1972), as well as a number of dry ranges in southern Nevada (McQuivey 1978) and Eastern California. I requested bighorn managers in Nevada, California, and Arizona to provide me with any examples of bighorn sheep populations persisting year around in what were known to be dry ranges; none were identified. By contrast there are thriving dense and stable populations in those desert ranges such as the Eldorado in Nevada, and the Black Mountains in Arizona, where desert bighorn have nearly unlimited access to water in the Colorado River.

The consistent and predictable behavior of desert bighorn sheep in exploiting water sources, both natural and manmade, defy an alternative conclusion other than this resource is very important to them, particularly during the hot-dry portion of the desert summer. To speculate that they only use these as a matter of convenience is to deny the value of studying the autecology of wildlife, as any recognized, repetitive habitat use or behavior can then be challenged as facultative use rather than being adaptive (Alcock 1975). Such habitat variables as food selection, thermal refugia, cover type, floral association, slope, etc would not be interpreted as having real value to those individuals using them.

What has changed since the provocative papers of Krausman and Broyles, who are collectively the two strongest challenges to this management strategy, is that we have finally, adequately documented bighorn mortalities due to dehydration. Though without rigid scientific controls, we have done the manipulative experiment in the natural system, that of removing water, and have now observed that bighorn and desert mule deer, hereafter referred as bura deer, (Odocoileus hemionus eremicus) will die as a result.

In these cases, succulent vegetation, nocturnal behavior, movement elsewhere in their home range, were all inadequate alternatives for these animals to survive. There is no basis to consider these events atypical. I assert these incidents render moot virtually all of the biological and most of the philosophical challenges to this management strategy. We have inadvertently and perhaps on occasion negligently, replicated this experiment too many times, in too many places. It is time we absorbed the lesson.

I have repeatedly observed that when water developments are properly built and sited in areas that exhibit healthy floral communities, it is a matter of 3 to 5 years before substantial bighorn and other wildlife use can be documented during the dry portion of the summer. This consistent seasonal use is a natural behavior. We also observe it at natural water sources. It is no different than other routinely observed animal behavior; natural behavior is adaptive and thus beneficial to these animals. That we have not yet learned to quantify this to our satisfaction, or that not all populations can be shown to have experienced a net increase (Broyles 1999), is irrelevant to the ecological and evolutionary significance of repeatedly observed behavior in free roaming wildlife.

I have read most of the literature pertinent to this topic in the U.S. Southwest. Much of it I have re-read a number of times. It is not, as currently inferred (Krausman 1997, 1999, Smith and Krausman 1988, Broyles 1995, 1997, Rosenstock 1999), equivocal on this topic.

The great preponderance of evidence gathered by numerous field observations by experienced investigators and managers of desert bighorn populations, document the strong affinity of bighorn sheep to water sources, and the general scarcity of these sources. The concept of providing additional reliable water sources to desert bighorn has stood the test and scrutiny of time. The reader desiring to learn more about some of the earlier applications of desert water development are referred to the work of John Russo (Russo 1956) J. Elder (Elder 1956), J. Wright (Wright 1959) and the Kofa NWR Annual Reports 1940-1950.

Water sources not only provide desert bighorn with the opportunity to re-hydrate, they are focal points of bighorn social behavior during the summer months (Simmons 1969, Olech 1979, Kirby 1999, and Pers. Observ.). The adaptive value of this social behavior to desert bighorn herds should not be overlooked nor minimized.

Several research studies (Smith & Henry 1985, Burkett & Thompson 1994, Cutler & Morrison 1998) have been completed that individually and especially together, make a strong argument that the effects of providing water on other vertebrate biota is negligible with no negative impacts noted.

## HISTORY

The idea that large herbivorous mammals are able to exist in the American deserts without access to free water has been speculated upon for nearly 100 years. One of the early influential naturalists that put this idea to print was Carl Lumholtz (Lumholtz 1912). Lumholtz reported that local vaqueros informed him that their cattle were able to graze the deserts of Sonora without drinking.

Ernest T. Seton (Seton 1929) first and then Jack O'conner (O'conner 1939) stated some sixty years ago that bighorn sheep, desert pronghorn, and desert mule deer could exist in areas devoid of free water.

Aldo Leopold (Leopold 1933) concluded that Southwestern whitetail deer, mule deer, and bighorn sheep can live on succulence alone.

Steve Gallizioli, Ed Webb, and J.T. Wright of the Arizona Game and Fish Department (AGFD 1958 - 1963) published a series of papers evaluating the effects of water developments on Gambel quail (Lophortyx gambelii). While the authors described high numbers utilizing particular waters, and increased populations in the vicinity of water, the general conclusion derived from their reports has been that water developments were of little value to Gambel quail populations.

David Brown (Brown 1984 and 1997) formerly of the AGFD, has been skeptical of the benefits of water to desert ungulates. He has suggested that desert bighorn sheep and bura deer, are able to maintain populations without the necessity of water.

Paul Krausman, a Wildlife Ecologist with the University of Arizona, published several papers (Krausman et al. 1985, 1986, 1995, 1996, 1997) that have subsequently been considered by some to provide the scientific basis from which to question the need for, and efficacy of, water developments for bighorn sheep.

Raymond Lee, formerly of the AGFD, (Lee 1993) commented in reference to bighorn surveys he had flown in Sonora, that many ranges there appeared xeric and ill suited for holding water for any period of time. Lee went on to state that Sonoran bighorn sheep were doing well without a water development program.

Bill Broyles, a Tucson based naturalist, like many if not most Southwestern field biologists (including this author), was partially influenced by the writings of the previously noted, as well as many other investigators. Broyles additionally formed many of his ideas and questions regarding water developments while traversing the great arid lands that comprise the Southwestern portion of Arizona and Northwest Sonora. Broyles (Broyles 1995, 1997, 1999, and numerous Pers. Comm.) was perhaps the first to publish professional papers soley challenging the efficacy and indeed the desirability of providing water to desert bighorn sheep. Mr. Broyles primary thesis has been that the government has failed to scientifically prove that free roaming desert bighorn require artificial water sources. He has identified a host of secondary potentially negative issues that he believes are additional reasons to cease water development construction & redevelopment until the appropriate research has been completed.

Largely in response to the challenges presented by Mr. Broyles, the AGFD convened a committee to evaluate the issue. The committee (including this author) represented the spectrum of wildlife managers and specialists with vastly varying desert ungulate work experience. The final White Paper (AGFD 1997) was somewhat equivocal regarding benefits to desert bighorn sheep. The narrative regarding well documented benefits comprised of 4 lines of text, the controversy portion of the narrative occupied 13 lines of text. The committee as a whole unfortunately did not reach these results by a consensus approach.

Steven Rosenstock of the Arizona Game and Fish Department (AGFD) published a paper (Rosenstock 1999) that was largely a byproduct of the White Paper effort. This paper concluded that water developments had "probably benefited some but not all" bighorn populations.

The direction this controversy has taken thus far, and might take in the future, has a direct impact involving the authority and decision ownership regarding which and whose management philosophy ought to be applied to bighorn sheep populations located on public lands. There is a schism between the perceived need to choose either classic Conservation Biology or an Ecosystem Management based; resource management prescription. This paper examines this apparent schism further and concludes there is no real contradiction of either school of thought when deploying wildlife water development strategies.

This effort will examine, evaluate, & critique, the primary literature that purport to challenge the provision of supplemental water to bighorn sheep. It also briefly discusses those principal studies and investigations that support this strategy.

I found a virtual void in the literature, as well as in recent discussions with bighorn managers that document desert bighorn populations maintaining themselves in the Sonoran or Mojave Deserts without access to water sources. There are by comparison, voluminous documents describing the use and importance of water sources to bighorn sheep.

## THE JUSTIFICATION FOR PROVIDING WATER SOURCES

The fundamental justification for water developments is the fact that they emulate if not duplicate, a natural occurring phenomena; perennial water sources exist in arid landscapes and these water sources are of seasonal importance to desert bighorn. In these areas where adequate natural sources exist, investigators can expect to find higher densities, advantageous herd structure (larger group size), and higher rates of recruitment. Where free water sources are ephemeral to the point of essentially lacking, we observe extant populations if present at all, are characterized by instability. On truly dry mountains, investigators rarely find resident bighorn sheep (Pers. Obs. McQuivey 1978, Richard Weaver Pers. Comm.). When we do, there is invariably a donor population adjacent to it, and thus these areas are likely functioning as sinks. These populations are at higher risk for extirpation. Herd unit extirpation is very undesirable from the meta-population management perspective.

The following cases, and the numerous older events that are inextricably linked to them, make a strong case for desert bighorn dependence on water sources. By comparison, the few cases of dwindling herds existing for short periods of time without apparent access to water make a far weaker argument for bighorn being able to persist without water. When this information is considered in conjunction with the behavior of bighorn around natural waters, the proof is compelling, the appropriate management direction clear.

## CASE HISTORIES OF LOSSES OF BIGHORN AT DRY WATER SOURCES

Group mortalities of desert bighorn at dry water sources, both natural and manmade, occur and have been documented to varying degrees. What has changed since Monsons paper ((Monson 1965) is the fact that Wildlife Managers and other individuals have happened upon known critical waters that had recently gone dry and have documented animals freshly dead and dying of obvious dehydration. The fact that these group mortalities occur repeatedly at dry sole source waters, in the period of summer, limit a reasonable person to a death-by-dehydration conclusion. This conclusion conforms to Ockham’s razor (Dasmann 1981), which states when several explanations will fit the known facts, the most simple explanation must be accepted. Dasmann notes this principle is to guide all scientific investigations.

These recent observations of desert bighorn and bura deer in the process of dying require a reasonable person to accept death by dehydration as the presumptive cause at the previously documented group mortality events.

This presumption of death by dehydration is also the simplest explanation that by far, best fits the evidence documented for 31 of the 45 desert bighorn (13 lambs drowned, 1 ewe tested positive for botulism) that were lost at the greatest group mortality yet documented - the Old Dad and Vermin guzzlers failure event of August 25, 1995 (Swift 1996). Though they have been uncontrolled experiments, past and recent water development failures have adequately proved the seasonal dependence of desert bighorn on water. The knowledge available via their deaths should not also be wasted.

While the number of carcasses observed at the dry water source is often in the range of 2 to 6, recent survey data obtained in California, gathered in conjunction with the Sheep Hole Mtns. guzzler failure event of July 2000, has indicated a potential actual loss of 75% of the estimated population (CDFG Pers. Comm.).

On August 6, 2000, two AGFD Wildlife Managers inspected a standard large volume water catchment (unit # 933) located in Western Arizona. When they arrived they observed an emaciated looking class II ram bedded near the storage tank. They observed it from a distance with binoculars and commented that it looked pretty bad and had likely come to the water to die. As they drove closer, the ram left the area. They noticed that the drinker was dry and that there was a freshly dead class IV ram lying in the shaded area by the storage tank. There was also a fresh carcass of a mature bura buck. Both of these carcasses were intact, the ram appeared to be the more dehydrated of the two. Inside the storage tank they found 14 ungulates that had jumped in through a gap between the rim of the tank and the roof over it. There were 11 bighorn and 3 bura deer inside the tank. All except 2 of the bura deer were still alive. The bighorn were classified as follows; 3 class I rams, 1 class III ram, 4 ewes, 2 yearlings (male and female), and 1 lamb. The class III ram and a ewe bolted out of the tank, the others did not attempt escape. The storage tank was now dry, except for urine spots on the floor. The Wildlife Managers provided these animals with an ice chest with approximately 15 l (4 gal.) of water. It was all consumed immediately by 6 of the bighorn sheep. The Wildlife Managers telephoned their supervisor for advice and assistance from Phoenix (water-hauling). They then dismantled a portion of the tank so the animals could exit, which they then did. A group of the bighorn remained on a nearby hill while the Wildlife Managers removed the two freshly dead (bloated) buras; a doe and a young buck from the tank. They also noted a young coyote dead outside on the site.

One of the Wildlife Managers advised me that he noticed when he dragged the mature bura away from the tank that there was a noticeable gap between his velvet and the antler core. I have handled a number of dead antlers with velvet (primarily road kills) and have never noted this. I suspect it may be indicative of the buck's level of dehydration when he died.

The outlet plumbing for the storage tank protrudes approximately 5 cm (2") above the tank floor, therefore when the float-regulated drinker went dry, there was ~ 2" of water remaining in the tank. The interpretation was that as these animals arrived to drink and found the drinker dry. They smelled the water remaining in the tank and jumped into the tank from higher elevations (backfill soil) around it, but could not or would not, jump out through the same gap from the lower elevation of the tank floor.

The Wildlife Managers surmised the larger antlers and horns on the 2 mature mortalities outside prevented them from being able to enter the tank. The residual water in the tank amounted to 1058 l per vertical 2.54 cm (280 g./1").

With 14 ungulates in the tank consuming 4 - 6 l/day each (15 - 17 g/day) and estimated evaporation removing another 212 l/day (55 g); this water probably lasted the trapped animals 5 to 7 days. The residual water in the tank, and shade permitted them to live while the mature ram and buck perished outside the tank.

The previous inspection on this development was on June 20, 2000. At that time there was 30.5 cm (12”) of water remaining.

Photographs documenting the scene were taken at the time by Dee Pfleger of the AGFD and later by the author and are depicted in figures 1 – 1.4.

I examined the # 933 site on October 3, 2000, 56 days later. Temperatures were still reaching 38 C + (low 100’s). September had been unusually hot in the desert. The immediate area (<.75 km) was dry with saguaros at ~ 75% turgid; ironwoods were green but beginning to turn a blue cast, creosote bushes were largely brown. At a distance of .75 km to the SW, the desert had received rains to the point the ocotillo were in leaf.

I observed 3 mule deer remains and the adult desert bighorn carcass. They were still largely intact skeletons with much of the hide still on, adjacent to the storage tank where they had been dragged (figure 1. & 1.1). I also noted the mummified remains of a young coyote. I measured the gap that the animals had in order to enter the tank, it was 45.7 cm (18”). The storage tank is a metal ring 7.3 m (24’) in diameter by 1.7 m (66”) deep with a capacity of ~ 69850 l (18452 G). On my area reconnaissance, I did find the remains of an adult bighorn ewe approximately 750 m to the NE that I estimated also to have died this summer (hair and hide remaining on bones). I speculate it was likely one of the released animals. I inspected 3 nearby horizontal and vertical mine shafts and found no bighorn remains in them.

I observed numerous ungulate pellet groups, all appeared to be getting old (lost their sheen & beginning to turn lighter); none were fresh. Abundant sheep beds with similar aged pellets were observed in the wind caves above the catchment to the E. and NE.

Numerous similarly aged deer pellets groups were observed on the trails leading in from the west (lower rolling terrain). By size, these pellets indicated deer of all age classes. There were no hoof prints on these trails nor near the water catchment. Nor were any seen on the 23 km (14 mi.) of silty road leading to and from site # 933. Interestingly, there were no predator scats or tracks observed in the area of the development either. This explains the carcasses being largely intact.

The fact that there was no recent detectable ungulate use indicated to me that it was likely all the liberated ungulates had probably died. I have documented a similar response (no further summer use) involving bura deer at another wildlife water that was allowed to go dry.

Cacti in the immediate area (< 100M) included saguaro (Cereus gigantea), staghorn cholla (Opuntia versicolor), Beavertail prickly pear (Opuntia basilaris), and Hedgehog (Echinocereus engelmannii). None of these cacti evidenced any attempt at recent use. The nearest Barrel cactus (Ferrocactus spp.) I could find were on rolling ridges located .75 km (.5 mi) to the SW. There was no evidence of bighorn sheep attempting to use any of these either. Approximately 50% of the mid-sized saguaros located 1 km to the NE in escape terrain evidenced relatively recent bighorn use (figure 1.4).

I later reviewed NOAA radar images for the area and determined it had rained twice in the area prior to this event. Precipitation in the North Plomosa block started June 21-22, producing 6 – 12mm (.25 -.5”) and again on July 31st, producing 2.5 – 6mm(.1 - .25”).

I measured the depth of water in the tank [AGFD had hauled 28390 l (7500 g) immediately after the event], at 680 mm (26.75”).
AGFD data indicate the water level was 610 mm (2’) on August 14, 2000. This data with additional precipitation estimates, substantiates my observation that post event utilization has been low to non existent.

From this water development failure, we can observe and infer the following;

1) That 1 mature bighorn sheep and a bura deer died of dehydration. The dead ewe I observed and the young ram the Wildlife Managers first observed likely died of dehydration, too.

2) That succulent cactus was available and likely used but was not a viable option for the bighorn to survive dehydration.

3) That these animals did not know of the nearest permanent water source (unit # 521) to this location which is 41 years old and located approximately 12 km (7.5 mi) South and SE of this location through largely contiguous (though bisected by an unfenced, recently paved road) habitat.

4) This dieoff occurred at a water development that is 15 years old. Its history has been that bighorn were slow to initially accept it and remain for the summer in the North end of the Plomosa Mtns (the establishment of a new herd unit in this North block was our original rationale for constructing the facility). When I last inspected it in June of 1992, it evidenced light use by desert mule deer, but no bighorn use (bighorn use is determined by beds & pellet groups inside the exclosure) was noted.

5) That until this dieoff event, the water development was functioning as per its original purpose.

The next several years’ monitoring efforts will indicate the biological significance of this event.

Unfortunately, the California Department of Fish and Game (CDFG) has been largely unwilling to share specific information on what (CDFG Per. Comm.) appears to have been a significant water development failure incident that happened during July of 2000. A CDFG water monitor volunteer inspected the Suds Hole Guzzler, a standard big game water development in the Sheep Hole Mountains located in the Mojave Desert. When he arrived he observed the drinker was dry and that there were multiple freshly dead bighorn sheep of both sexes. All carcasses were intact and showed signs of being dehydrated when they died. A number of live bighorn were also observed. A coyote was observed to attack and kill an obviously dehydrated ewe while he was at the site.

A helicopter survey of the range was completed that week. Another guzzler (“Bear Claw”) to the South of the Suds Hole unit was also found to be dry and there were mortalities observed there as well. The survey purportedly resulted in an approximate 75% reduction from what was observed during surveys the year prior.

Witham (Witham 1982) described a number of mortalities he investigated as part of his research on bighorn sheep in Western Arizona.

On July 13, 1979, he found a 9-year-old ram, freshly dead at a waterhole (Lazarus tank) in the Plomosa Mtns. The waterhole had dried up between the 7th and 9th of July. The ram was collected and a necropsy performed. It was found to be in fairly good condition with substantial fat in the abdominal cavity. Of considerable interest is the fact this ram was found to be 29% lighter than the average weight for comparable rams at that time of year. This value approximates the accepted lethal level of dehydration for bighorn. Further evidence for this conclusion was Witham's observation of 5 visibly dehydrated live bighorn some 20 m away from this ram's carcass.

Five days later a hiker found another ram, a 3-year-old, dead at this same waterhole. The hiker reported that it appeared to have been dead 2 or 3 days prior to his finding it.

On July 21, 5 mature rams were found dead in a cave 2.8 km (1.75 mi.) NW of this site. They all appeared to have approximately the same time of death as the 3-year-old ram. Witham noted that 3 of these rams evidenced signs of recent rutting activity.

I recently interviewed Mr. Witham about his observations and determined that the cave where the 5 mature rams were found was, as I had suspected, in the immediate area of another tinaja known as "Little Bones". Witham informed me that Little Bones had recently gone dry as well.

From Mr. Witham's observations, we can infer that these animals did not know of the nearest permanent water source (unit # 521) to this location which is 41 years old and located approximately 6.5 km (4 mi) North and NE through contiguous habitat. We can conclude that the mature male bighorn sheep died of dehydration. We can also conclude that some of the animals died as a group at the 2 water sources.

I am familiar with this area and have observed that succulent cactus - Barrel, Mammalaria, and Saguaro - are available, but these were apparently not a viable option for these bighorn to survive dehydration.

It is noteworthy that the distance to the nearest available water involving the Plomosa water failure event of July 1979, is very similar to that involving the bighorn dieoff at the Old Dad Peak guzzler failure event of August 1995, where the nearest functioning alternative water (Kerr guzzler) was 7 km (4.4 mi.).

Monson (Monson 1965) of the Bureau of Sport Fisheries and Wildlife was apparently the first individual to recognize and document a pattern involving group mortalities at wildlife waters. Monson describes 4 separate events involving some 20+ known bighorn losses. Monson acknowledged that these losses all were similar in that they occurred in summer, and at waterholes. Indeed, one of the 4 incident's observers concluded that no water or bad water was likely the cause of the 6 to 10 bighorn he found dead. Nevertheless, Monson concluded that dehydration was an unlikely cause of these losses. He arrived at this by stating "bighorn were known to travel to other waters". All of Monson's waters are or would be designated today as critical waters for bighorn sheep. (critical waters are those waters used by bighorn and isolated or part of a local cluster of water sources, greater than 5 km from the nearest alternative water source.).

Desert bighorn sheep and bura deer have been documented to perish at a number of dry water developments both natural and manmade (Table 1).

Another indication of how dependent desert bighorn are on water sources can be derived from summer releases of freshly captured desert bighorn. The Arizona Game and Fish Department documented (AGFD 1994) on at least three occasions that 40% + loss of desert bighorn occurred when these animals were released in July (the best

## Table 1

**Losses of bighorn sheep at dry water sources.**

| LOCATION | DATE | OBSERVER | LOSS | COMMENTS |
|---|---|---|---|---|
| Mojave tanks Trigo Mtns. Az. | 1934 | H. Morrow | 23 bighorn | Kofa NWR Annual Rept. 1944 |
| Little White Tanks Kofa NWR Az. | 1943 | Lt. Hatfield | 1 ram 5 bura | No action |
| 4 locations | Various | G. Monson USFWS | 20 + bighorn | See narrative |
| Stubbe Spring Joshua Tree NM Ca. | Approx 1968 | L. Lutz | 2 rams | Guzzler constructed |
| Butterfly tank. Estrella Mtns. Az | July 1987 | J. Gunn AGFD | Yrlg ram 1 ewe | Facility re-developed 1990 |
| Lazarus tank Plomosa Mtns. Az. | July 1983 | J. Witham | 2 | 5 live dehydrated sheep observed |
| Little Bones cave Plomosa Mtns. Az. | July 1983 | J. Witham | 5 | See narrative |
| Muddy Mtns. guzzler # 5 Muddy Mtns. Nev. | July 1994 | P. Cummings NDOW | 2 ewes | Dry ephemeral seep & water development |
| Trigo Tinajas Trigo Mtns. Az. | Approx 1994 | G. Searles | Multiple bighorn | |
| Vermin tank guzzler Old Dad Mtns. Ca. | August 1995 | A.Pauli CDFG | 3 bighorn | See Swift 1996 |
| Old Dad Pk. guzzler Old Dad Mtns. Ca. | August 1995 | A.Pauli CDFG | 26 bighorn | See Swift 1996 |
| Suds Hole guzzler Sheep Hole Mtns. Ca. | July 2000 | CDFG | 6 bighorn | CDFG withholding specific information |
| Bear claw guzzler Sheep Hole Mtns. Ca. | July 2000 | CDFG | Multiple bighorn | CDFG withholding specific information |
| Catchment # 933 Plomosa Mtns. Az. | August 2000 | D. Pfleger AGFD | 1 ram 1 bura | See narrative |

month to trap them at Lake Mead) in Game Management Unit 16A located in Western Arizona. The authors noted that 12 sheep captured at the same time and released in SW Colorado suffered no losses during their first few months. Significantly, the authors state that most of the bighorn that remained in the summer release areas (water development sites) survived, while most of those sheep that left the release areas died within 2 months. The authors note the contrast that for one winter release in this area, 5 of 6 telemetered sheep left the release site with no mortalities documented. The magnitude of these summer losses resulted in the authors recommending summer releases be restricted to higher elevations.

We can gain additional insight into the dependence of desert bighorn sheep on water sources by considering their behavior around “death traps”. These death traps are naturally occurring bedrock tinajas with smooth (often angling inward beyond vertical) walls that when full after a recharge event, serve many species of wildlife. As the water level recedes, they progressively become more difficult for various wildlife species to utilize them.

For desert bighorn, which typically begin to utilize water sources in mid to late June, many death traps will typically be at a minus .6 to .9 m level (2 to 3’) depleted condition. Therefore desert bighorn likely have to initially assess them for safe use.

Eventually, these tinajas can and do cause desert bighorn and often desert mule deer to become trapped and drown and or starve to death. In one extraordinary case 34 bighorn were lost (Mensch 1969). Desert bighorn are renowned for their ability to evaluate and judge their capabilities to scramble over the nearly vertical canyon walls, cliffs and other terrain. They are rarely found as victims of accidental falls. My few observations of apparent losses (below cliffs) have been lambs. Adult bighorn have never been documented to become trapped in dry vertical pits (natural depressions or mine shafts). Nor have they been documented to become trapped in death traps during the cooler months. It is incongruous then that adult bighorn should make the fatal mistake of entering death traps for the purpose of re-hydration unless their immediate survival was threatened.

What other rationale can explain this behavior persisting over evolutionary periods of time? When the immediate survival of an animal (including man) is threatened, a consistently observed response is for the animal to deal sequentially with the most immediate threat to its continued existence. Those bighorn that are able to reach the water, re-hydrate and safely exit realize a higher reproductive fitness and thus this behavior is selected for.

The conclusion that the bighorn are desperate, rather than victims of habituation as the water level recedes, can be derived from the recent water development failure (Arizona development # 933 failure event of August 6, 2000). In this case, 11 bighorn and 3 bura deer jumped inside a nearly dry storage reservoir with but an 18” gap between the rim of the tank and its roof structure and were subsequently trapped.

Additional evidence that these death trap losses are directly tied to water dependence can be derived from the fact that these losses are unknown from more mesic habitats that comprise the core of North American bighorn sheep habitat. I note that other sure-footed mammalian wildlife that are known to be facultative users of surface waters such as grey fox (Urocyon cinereoargentus) and bobcats (Felis rufus), has not been documented to become trapped in bedrock death traps.

Desert bighorn sheep have been documented to perish in various death traps in a number of desert areas over many years (Table 2).

# Table 2

**Bighorn Sheep losses in death traps**

| LOCATION | DATE | OBSERVER | LOSS | COMMENTS |
|---|---|---|---|---|
| White Tanks Tank Mtns. Az. | Approx 1954 | J. Russo AGFD | Undetermined ungulate bones. | Steps added |
| Dead Deer tank Eagletail Mtns. Az. | Approx 1956 | J. Russo AGFD | Multiple bighorn and bura deer | No action |
| Pintwater Range Nv. | Post 1962 | Unknown | 1 Ram | McQuivey 1978 |
| N. Eldorado Tinaja Nv. | Post 1962 | Unknown | 1 Ram | McQuivey 1978 |
| Julian Wash death trap Chocolate Mtns. Ca. | Fall 1968 | J. Mensch CDFG | 34 bighorn; various sex & age classes | Steps added |
| Golden Door cistern Black Mtns. Az. | Approx 1984 AGFD | A.Fuller | 11 bighorn; various sex & age classes | Metal grate cover installed |
| Hidden Valley Pothole Trigo Mtns. Az. | Approx 1988 | R. Remington AGFD | Undetermined; bighorn & burro | Elaborate spiral ramp constructed |
| Marble quarry Carrara canyon Bare Mtns Nv. | Summer 1992 | B.Adkins NDOW | 4 bighorn; 2 ewes 2 lambs | Unknown |
| Muerto tank Sand tank Mtns. Az. | Approx 1994 | J. Gunn AGFD | Undetermined; Numerous ungulate bones | No action |
| Red Tank Kofa NWR Az. | Summer of 1996 | R. Henry AGFD | > 6 bighorn; 1 ram, 5 ewes, + 2- 3 unknown | Steps added |
| Old Moonshine tank Kofa NWR | Summer of 1996 | R. Henry AGFD | 3 bighorn; 2 rams 1 ewe, 3 bura deer; 2 bucks, 1 doe | Steps added |
| Maggot tank Kofa NWR Az. | Summer of 1996 | R. Henry AGFD | 9 bighorn; (1 ram 7 ewes, 1 unknown) 2 bura deer; doe & fawn | Steps added |

## REVIEW OF THE RESEARCH THAT SUPPORTS WATER DEVELOPMENT STRATEGIES

It has been asserted that there is a need to do more research prior to building more “artificial waters”. I contend an overwhelming amount of quality research has been completed that provides the scientific basis for this strategy. It is not the purpose of this paper to repeat what others have done well already. The reader is referred to Krausman (Krausman 1996 and 1997) for a comprehensive synopsis of research pertaining to bighorn sheep and water. I do need to briefly discuss what I find to be the most pertinent.

Leslie and Douglas (Leslie and Douglas 1979) published the results of their investigations regarding aspects of the ecology of a desert bighorn herd in the River Mountains of Southwest Nevada. The results of this fairly long term study indicated that these Mountains previously only were occupied by sheep during favorable periods with an observed annual summer exodus to the Colorado River. In 1940 a manmade water source became available and the River Mountain population became largely isolated by a highway. The population was estimated 37-60 animals in 1964-65.

The population was estimated at 88 by 1969. Forty four bighorn were translocated out of the River Mountains in the 8 year period of 1969 to 1977.

In 1973 a second (man made) watering source became available to the sheep, and a large percentage of the population began watering there, effectively doubling the foraging area available to this herd. In October of 1973 the population was estimated at 205 animals. In the summer of 1975 a third water became available and the population was estimated that fall at 278 animals. The authors provide additional credence to these estimates by also comparing changes in the age structure of the population which also indicate a rapidly expanding population.

A key point regarding the addition of water sources in the River Mountains is that they were not developed for bighorn sheep. They were inadvertent water releases from other infrastructure (sewage leach fields, a pumping plant and a Govt. horse stable). The fact that these waters were not intended for bighorn use and thus not situated in the best bighorn habitat, negates the criticism that we build waters in the areas sheep prefer to inhabit, so that subsequent telemetry data is of little value (Broyles 1997) in interpreting the waters’ importance to bighorn. Leslie and Douglas documented that rainfall would cause the sheep to vacate the areas around these water sources. Their telemetry data indicated 84% of those sheep would be found within 2 km of these water sources during summer. Investigators such as Cunningham (Cunningham 1982), Olech (Olech 1979), and Bristow (1996) documented similar summer aggregations of telemetered sheep around natural and manmade water sources.

Despite human induced encroachment on all sides, the River Mountains have continued to support a stable and productive desert bighorn population numbering around 300. They have provided numerous bighorn for translocation as well as sport harvest.

Turner (Turner 1970) documented that free roaming desert bighorn varied their water intake depending on how long it had been since the animal had last drank. This value ranged from 11 to 16% of the animal’s body weight for a one-day period up to 14.7 to 18.7% of the animal’s body weight if it had been 5 days prior. This data demonstrates a progressive dehydration of these animals in their natural environment. Turner reported that dehydration exceeding 20% of body weight is lethal.

Hailey (Hailey 1967), evaluated water utilization by 30 desert bighorn on the Black Gap Wildlife Area Enclosure in West Texas. This paper is significant in part because it demonstrates and quantifies the use of water developments by desert bighorn even in the comparatively lush Chihuahuan Desert, which also extends into Southeastern Arizona. Hailey's paper correlates the availability of water with high lamb production and recruitment.

McQuivey (McQuivey 1978) reported the effect of adding water sources on the summer range of desert bighorn. He found the addition of water allowed bighorn to remain in the Desert Range during summer when prior to this action, they would move to the Sheep Range during the summer. McQuivey reports that 82% of 488 bighorn classified during a July survey were found within 2 mile radius of known water sources. McQuivey notes that only 15 to 20% of the occupied habitat is available to bighorn during the summer months due to water availability.
He notes bighorn surveys indicate this situation is reversed in Central Nevada Ranges where water is not limiting and bighorn are widely distributed through the suitable habitat. McQuivey identified a number of dry ranges in Nevada that supported bighorn during the cooler months but did not contain sheep during the summer.

## CASE HISTORIES THAT SUPPORT WATER DEVELOPMENT STRATEGIES

The Specter Mountains are comprised of approximately 170 sq. km (66 sq. mi) located in the Mojave Desert North of Las Vegas Nevada. The range was determined to be essentially dry and without a resident population of bighorn sheep. Between 1989 and 1991, 6 water developments were constructed. In 1990, 19 desert bighorn were released and supplemented with 20 more in 1993, and 5 additional rams released in 1995. In 1998 a survey resulted in 119 bighorn being classified and 15 bighorn being captured for translocation out of the range (NDOW Per. Comm).

The Cabeza Prieta National Wildlife Refuge (CPNWR) in Southwest Arizona is an excellent example demonstrating the stability of desert bighorn populations with access to water and the comparative instability of those that do not. The CPNWR bighorn surveys have been standardized and occur every 3 years. Between 1993 & 1999 (a period of atypical summer & winter drought in many Arizona desert areas), these 3 surveys resulted in a progressive 46% decrease in observations for the Growler Range, and a 84% decrease in observations for the Granite Range. Both of these mountains are thought to be devoid of perennial bighorn waters. The total number of bighorn observed for these 2 ranges in 1999 was 63 individuals. The surveys observed by comparison, a 2% decrease in the Cabeza Prieta Mountains, a 14% decrease in the Sierra Pinta Range, and a 23% increase in the Mohawk/Bryan complex. This latter group of mountains all contain minimal perennial bighorn waters. The total number of bighorn observed for these 3 ranges in 1999 was 242 individuals. Other bighorn populations in SW Arizona demonstrated similar responses and will be discussed below.

The Kofa National Wildlife Refuge is an outstanding example of a robust desert bighorn population that is characterized by remarkable stability. It also is an example at the landscape level, where the Sonoran Desert contains substantial natural occurring water sources. With a mountainous area of approximately 1200 sq. km (450 sq. mi), there are 11 springs, 7 natural tinajas, and 25 ephemeral sites that have been improved to various degrees (Sanchez & Haderlie 1988). In the 9 year interval of 1987 through 1994, there were approximately 350 bighorn removed for transplants and approximately 110 rams harvested by sport hunting. Population estimates for this interval ranged from 638 to 929 bighorn sheep (USDI 1996). The population to date is estimated at approximately 900 (USFW Per. Comm.)

The Gila Bend Mountains located in Game Management Unit 39 show where an integrated approach to bighorn sheep recovery has resulted in a very desirable outcome. Initially, the herd was virtually extirpated. The one natural spring in the area had been heavily exploited by miners and later livestock, and the bighorns' access to historic water; the Gila River largely denied by water diversion, and tamarisk invasion.

Between 1987 and 1993, 3 strategically placed bighorn waters were constructed (Signal Pk., Woolsey Pk., Bunyan Pk.). There were 4 releases of bighorns totaling approximately 50 individuals within this same time period. Bighorn surveys in 1992 and 1993 showed an average of 24 individuals. In 1997 and 1999, the surveys resulted in an average of 90 bighorn being observed. I have also observed increasingly heavy use of these new water sources.

The Eagletail Mountains located in Game Management Unit 41 are another example of an integrated approach to bighorn sheep recovery resulting in another desirable outcome. In the recent past, the herd was extant but static at a low density with surveys observing about 35 individuals. The bighorn had access to limited historic water; a known death trap, and a quasi perennial spring which had also been exploited by livestock. In 1990, 1 new tinaja (Gray tank) was constructed, and another (Anvil tank) was renovated in 1989. There were also 2 releases in 1984 totaling 16 individuals. Another important water source (Triple eye) was enlarged and renovated in January of 1996. A bighorn survey in 1994 resulted in approximately 35 individuals. In 1997, 75 bighorn were classified despite 10 bighorn being removed that year for a translocation. The recent survey of October 2000 resulted in 140 bighorn being observed.

The Sierra Estrella Mountains are located in central Arizona adjacent to Phoenix. They contained limited natural water; 2 ephemeral tinajas and a quasi-perennial spring. The spring may have been more reliable in the past. There were undoubtedly opportunities for bighorn to access the Gila and Santa Cruz Rivers prior to settlement.
There are approximately 225 sq. km (87 sq. mi) of good to excellent habitat available. Due to heavily bouldered steep slopes, there are few deer or peccaries present. There are extensive rock murals depicting bighorn and bighorn hunting along the base of the mountain.

The AGFD has been surveying this mountain via helicopter for over 20 years. Bighorn counts ranged from 11 to 18 individuals. We believed these to be good surveys, since often all of the sheep would be found in just one or 2 groups near a then-ephemeral tinaja named Butterfly tank. The AGFD, ADBSS, and BLM cooperated to renovate the two ephemeral tinajas in 1990. Large tinajas over 3 m deep (10') were the result of our efforts. I have monitored these sites and documented that they have not been dry since 1990. My annual monitoring (pellet groups, bed sites, browse utilization) has also indicated progressively greater bighorn utilization. Surveys are flown in this range every 3 years. In the 2 surveys immediately preceding the tinaja renovations, the bighorn observed per hour was 4.0. In the latest 2 surveys, we reached 10.1 sheep per hour with 38 individuals as the maximum count.

In 1993, the AGFD and ADBSS constructed a new water development (Star Catchment unit # 1039) in the NW portion of the mountain range. It is approximately 13 km (8 mi) North NW of the nearest perennial water source (Butterfly tank). After seven years of biannual monitoring, I have yet to detect bighorn use of this development. It will be interesting to observe as this population continues to expand, at what point bighorn discover and become resident in this portion of the mountain as we experienced with unit # 933 in the Plomosa Mtns.

Other cases where water developments have been implemented with outstanding success in terms of bighorn population response in what were essentially dry mountains include the Old Dad/Kelso and Marble Mtns in California and the Spotted

Mountains in Nevada.
The Table Top Mtn. area of Game Management Unit 40A in central Arizona is an example of a desert mountain that has not been managed for bighorn sheep recovery. In the abnormally wet spring of 1993, a survey observed 34 bighorn sheep. By the fall of 1993 the survey yielded only 13 observations. In 1995, the survey produced 18 observations. In 1998, there were only 5 observations. A proposal to construct a water development on the top of this mesa has languished for 10 years due to the 1990 change in status to wilderness for this particular mountain. That bighorn populations in these dry ranges can decline to the point of virtual extirpation is demonstrated by the fact that in the fall of 1981, we failed to find any bighorn on Table Top Mountain during our survey. Thus it is probable that this mountain is functioning as a sink habitat to adjacent populations.

The Maria/McCoy/Palen Mtn. complex in Eastern California is another example of an extensive desert mountain complex of approximately 650 sq. km (250 sq. mi.) that has not been managed for bighorn sheep recovery. Dick Weaver, formerly of the CDFG informed me that there is only one reliable water source (Mojave Tank) in this enormous area and that bighorn historically utilized it. Apparently an extended drought and possibly illegal take in the 1950s resulted in this tinaja going dry and the population was extirpated. Since that time, the complex has remained largely devoid of water sources and bighorn sheep have failed to re-colonize the area.

The Gila Mountains located in Game Management Unit 40B in southwest Arizona have been effectively divided into 2 blocks by the construction of Interstate 8/ Hwy 84. The northern portion comprises approximately 52 sq. km (20 sq. mi) and contains no known reliable water sources nor a population of desert bighorn sheep. There is a popular hiking route to the radio towers at the summit of the north portion and there have been no reports to the AGFD of bighorn sheep sightings in this northern area. One of the Yuma-based AGFD biologists hikes to this summit twice a week. There has only been one recent sighting of bighorn in the northern block and that was adjacent to Interstate 8.

The southern portion of the range comprises approximately 250 sq. km (97 sq. mi) and contains 3 fairly reliable natural waters. Surveys are likely very conservative, since these mountains are composed largely of boulders of light granite. A recent survey of a portion of the southern block resulted in 37 individuals observed. If water were not an important habitat component for desert bighorn, one should expect them to occur in the northern block of these mountains proportional to the available habitat (approximately 20%) of the level they occur in the southern portion. This southern portion has in the last 5 years had a very ambitious water development (7) and re-development (2) prescription implemented. This range should be an excellent future case study of the effects of additional water on desert bighorn sheep.

## REVIEW OF THE RESEARCH & ARGUMENTS THAT CHALLENGE WATER DEVELOPMENT STRATEGIES

The principal challenge to providing water to desert bighorn sheep has been Paul Krausman and Bill Broyles of Tucson Arizona. I will first review their arguments and finally, consider the arguments put forth by David Brown and Ray Lee formerly of the Arizona Game and Fish Department. That two of these papers are cited to purport bighorn populations can persist independently of water, leaves me incredulous. Independently and together, they make no such case and indeed describe populations in the process of becoming extirpated. It is demonstrative that the downward trend of both of these populations has been arrested with the bighorn discovering and using water sources that have been provided for them.

Paul Krausman, a prominent ungulate ecologist with the University of Arizona dumbfounded many desert natural resource managers when he published two of his conclusions derived from his comprehensive bighorn research in the Little Harquahala Mtns. of Arizona. His conclusions were that bighorn sheep could persist in desert ranges devoid of water sources by feeding on Barrel cactus (Ferocactus spp.) (Krausman and Warrick 1989), and that bighorn sheep were not attracted to water developments (Krausman 1996). Krausman further stated that water development construction could actually be detrimental to bighorn due to increased competition for forage with deer and exotic ungulates (Krausman 1985,1986, 1995). In order to bolster these conclusions, Krausman referenced another study (Watt 1979) of a bighorn population in the Big Hatchet Mtns. of New Mexico.

Krausman's conclusions have been subsequently referenced by bighorn investigators including Nancy Andrews (Andrews 1999), Pamela Swift (Swift 1996), McCarty and Bailey (McCarty 1994). Bill Broyles has also relied on Krausman's work to buttress some of his arguments (Broyles 1995).
While I have no argument with Krausman's scientific expertise, methods, or results, I am in disagreement with him in terms of the significance and the interpretation that he and others have subsequently derived from portions of his work. A review and evaluation of Krausman's study in the Little Harquahala Mountains and the situation regarding the bighorn herd in the Big Hatchet Mtns. is therefore warranted.

The desert bighorn population in the Little Harquahala Mtns. was a comparatively small (20 – 30) and a transitory one with the Harquahala Mtns to the East, and pre U.S. 60, with the Granite Wash/Harcuvar Mtns. to the North. These sheep were becoming progressively more isolated by the time of Krausman's study. Of 17 telemetered bighorn in the population over a period of 5 years, Krausman subsequently attached much importance to the fact that two of the ewes were documented in the summer of 1983 to go 10 days with out drinking, and that they appeared to rely on barrel cactus pulp to maintain their water balance. Krausman did not attempt to reconcile his conclusion and subsequent management recommendations with Turner's research (Turner 1973) that indicated when Barrel and other cacti were dehydrated, they actually required more water for bighorn to process the accumulated salts in them than the water they provided to the sheep.

Krausman unfortunately did not discuss or relate the consequences of this cactus feeding behavior to the overall viability of the herd unit, including parameters such as lamb production and recruitment. The fact that neither of these ewes had a lamb with her during this 10 day study period, nor was aggregating with other ewes, with a rutting ram in attendance, would indicate this is not a normal (nor desirable) situation and possibly an adult survival strategy. While Krausman has stated (Valdez 1999) this population exhibited recruitment (though I note, he re-defined this term as lambs surviving to 6 months of age) at 21%, there must have been substantial mortality after this first 6 month period, as this population appears to have been regressing rather than expanding. The bighorn herd immediately adjacent to the east which Krausman documented as providing individuals to the Little Harquahala herd has in fact dwindled to virtual extirpation in the decade following his work, providing further evidence that this area as a whole was functioning as a sink habitat.

Krausman did report a significantly higher rate of mortality in Little Harquahala rams compared to an adjacent bighorn population that reportedly had access to water sources. That this population was not recruiting enough bighorn to offset mortality indicates the area was functioning as a "population sink" as described by Pulliam (Pulliam 1988). In his discussion regarding species conservation, Pulliam warns that an investigator in sink habitats can easily be misled about the habitat requirements of a species and that population management decisions based

on research in sink habitats could lead to undesirable results.
Krausman also failed to consider a management recommendation stated earlier by Simmons (Simmons 1969) "Water surveys should be continued until the dry ewes that have watered, and return to water again. This may be a minimum time span of 10 days".

Krausman continued to closely study the bighorn herd in the little Harquahalas. In 1985 & 1986, 2 bighorn water developments ("Gravel Pit" & Harquar tank) were constructed at locations recommended by Krausman. Of these, Harquar tank functioned as an ephemeral site at best. The other facility was located in an isolated block of the range that was separated from the rest of the range by a road.

Krausman (Krausman 1986) documented that heavy truck traffic in 1982 on this road caused the bighorn to greatly decrease their use of this isolated block of the mountain.

Thus I observe there was one unreliable water and one isolated water source available to these bighorn. Krausman (Krausman 1995) subsequently published a paper in the Journal of Wildlife Management describing the responses of desert ungulates to water developments. He concluded without discussing any of the above, that bighorn sheep in the Little Harquahala Mtns. were not attracted to water developments. While Krausmans conclusion that desert bighorn were not attracted to these water developments was factually correct at that point in time, in light of Krausman being aware of the above information, it is clearly a misleading conclusion from a resource management perspective.

Another aspect that should be considered with this population is that the Little Harquahala Mountains, unlike many desert ranges are riddled with abandoned mine shafts. Obviously these are not natural though they are analogous to the uncommonly distributed caves that bighorn are well documented to use as thermal cover. I have observed on a number of occasions, desert bighorn bedding during summer, well inside these mine shafts. The Little Harquahala bighorns were also likely to be better able to maintain their water balance by utilizing these manmade structures.

Krausman's conclusion that bighorn were not attracted to water developments did not pass the test of time. I have repeatedly documented that it often takes from 3 to 7 years for bighorn to habituate to a new water source. In October of 1993 I inspected the Gravel Pit catchment and documented significant use (multiple beds & pellet groups of all sizes) of bighorn sheep at this site. This summer use has continued and increased to the present time.

Krausman and Broyles have also referenced the work of Tom Watt (Watt 1979) to strengthen their arguments that desert bighorn have been documented to persist without using water. I have therefore reviewed his paper regarding the status of desert bighorn in the Big Hatchet Mountains on New Mexico. While I am not familiar with the Big Hatchets, I am familiar with similar adjacent ranges such as the Pelloncillo and Animas Mountains. From a western Arizona perspective, these Chihuahuan Desert mountains are very rich in forage. They also receive predictable summer precipitation. Unfortunately, range fences, domestic livestock operations and fire suppression greatly degrade their current value for bighorn.

Watt describes the population as being in jeopardy and noted adult mortality approached 50% over 2 years of his study dropping precipitously from 22 individuals down to 10 by his studies end in 1978. The population also evidenced chronic low recruitment. Of 11 lambs born, none were recruited in to the population. Watt's outlook for this herd was poor, he described the population as headed for extinction if the rate of decrease continued.

Like Krausman's study in the Little Harquahala Mtns., Watt's study can tell us much about how not to manage a bighorn population. These 2 studies individually and together make a very weak argument for treating water management as anything

less than a critical habitat component (Krausman 1997, 2000).
I contacted Eric Rominger of the New Mexico Game and Fish Department to ascertain the current status of this herd. Rominger provided the following information. Since Watts work their have been 3 supplemental transplants (39 bighorn) as well as the addition of additional water developments. Rominger has documented substantial evidence of utilization (multiple beds within 100 m) of one water source in the Big Hatchets as well as the first documented year around use in the Little Hatchet Mountains after 2 wildlife waters were constructed there in 1986.

Rominger also reported recently investigating a puma kill of a bighorn within 50 m of a cattle water located at the mouth of a canyon. He reports the population is currently considered stable at 60 individuals.

Krausman has also considered water sources important to desert bighorn. With Berner (Berner 1992) in a paper evaluating bighorn habitat in the Mojave Desert, he provides up to 40 points for water out of a possible 130 point habitat scoring model. With Smith (Smith 1988) he recommends that waters be constructed in high quality habitats at 3 – 5 km intervals. He does however again reference his 1985 work and cautions once again that sheep may have existed on dry ranges for thousands of years.

Bill Broyles, a naturalist residing in Tucson Arizona has been probably the most outspoken critic of the current process of providing water sources to desert bighorn sheep. Mr. Broyles (Broyles 1995, 1997, 1999) in addition to numerous Per. Comm.) was probably the first to publish papers solely challenging the efficacy and indeed the desirability of providing water to desert bighorn sheep.

Broyles primary challenge is bifurcated; that the effects of building artificial waters in the desert are unknown, and that the government has failed to prove that free roaming desert bighorn require artificial water sources. He has additionally identified a host of secondary potentially negative issues that he believes are additional reasons to cease water development construction & even redevelopment until the appropriate research has been completed.

I assert recent and past documentation of multiple desert bighorn of all sex and age classes, perishing at dry water sources (natural and manmade) render moot most if not all of Broyles primary contention that bighorn should be managed in a more "natural" manner.

My primary refutation of Mr. Broyles arguments lies in 3 arenas. They are;

- The consistent and predictable behavior of desert bighorn sheep in exploiting water sources, both natural and manmade, defy an alternative conclusion other than this resource is very important to them, particularly during the hot-dry portion of the desert summer. To speculate that they only use these as a matter of convenience is to deny the value of studying the autecology of wildlife, as any repetitive habitat use or behavior that is noted can then be challenged as facultative use rather than being adaptive (Alcock 1975). Such habitat variables as food selection, thermal refugia, cover type, floral association, slope, etc would not be interpreted as having real value to those individuals utilizing them.

- All Southwestern desert bighorn populations that are thriving (recruitment in the range of 25-30:100 ewes) have access to reliable water sources. These sources range from natural tinajas and water developments up to and including the riverine canyons along the Colorado River. Desert mountains that are thought to be virtually devoid of reliable water sources (springs and/or tinajas less than 4 to 5' deep) typically have low bighorn populations and often none at all. I suggest these areas are marginal habitats in normal years and function as population sinks during drought cycles.

- The government is under no obligation to prove the effect of a specific management action. Management of wildlife has long been recognized (Leopold 1948) to be a blend of science and art. Wildlife management is understood not to be nearly as pure and orderly, to use the classic example, a chemistry experiment where a given quantity of precipitate is formed each and every time the experiment is conducted. There are any number of extant wildlife management techniques that the government cannot prove, such as hunting season lengths, bag limits, road closures, installing nest platforms, reducing grazing or utilizing prescribed fires to enhance forage conditions, etc. Few if any of these techniques are "proven" or efficacious in every situation.

Field manipulations are implemented because they generally result in desired outcomes. They all have a logical basis via analogous natural processes.

Broyles identified 2 challenges to this management strategy that possess enough merit and appeal that a number of other biologists have repeated them, thus they should be given consideration. These challenges are as follows;

Single Species Management:

A repeated criticism of water development management strategies has been that it constitutes "single species management". Some natural resource management agencies have committed themselves to managing resources utilizing an "ecosystem approach".

While water developments are typically "targeted" at and labeled as "sheep", "pronghorn", or "deer" waters, the reason for this labeling is to establish human parameters such as funding, maintenance responsibilities, time-frames, etc. All water sources see a great variety of wildlife use. We have observed the gamut, ranging from gila monsters to bats, eagles to bighorns (Elder 1956). In reality, water developments are anything but "single species management".

This "single species management" label could be placed on various hunt strategies or survey efforts but the label does not belong here. There is nothing inherently wrong with "single species management". The bald eagle nest watch is such an example, as is propagating black footed ferrets for subsequent release. These "single species management" strategies are building blocks toward "ecosystem recovery". Thus a classic conservation biology approach can be integrated seamlessly with an ecosystem management philosophy.

Ecosystem impacts:

"Ecosystem impacts" generally refer to the concerns that "artificial" water developments facilitate establishment of exotic species, and/or that they upset natural balances between species. Some of the proponents of this challenge have even stated that water developments are altering the evolutionary process of Sonoran pronghorns and desert bighorn sheep in these species achieving independence from free water.

The "ecosystem impacts" criticism appears to be a formidable challenge until one considers the fact that a man made water development replicates a natural occurring phenomena; free water in the desert. What are the "ecosystem effects" surrounding natural waters such as Tinajas Altas, or on a larger scale, the Colorado River, where desert flora and fauna have had to deal with concentrations of native ungulates for thousands of years? Native ungulates have not been documented to significantly degrade desert floral communities. The areas within 1.5 km (.9 mi) of water sources do receive substantial use for 1 to 3 months of the year, however bighorns and bura deer invariably vacate these areas for other areas once the area receives precipitation.

Proponents of this challenge need to develop a coherent argument that differentiates the biological results between a geologic event producing a tinaja, and humans enhancing or constructing another.

Those individuals who believe we are altering the course of evolution ought to pause and review the past 100 years of floral change and fragmentation of our southwestern deserts. Only the most fortuitous assemblage of mutations could possibly keep pace with this human induced rate of change. Even in the comparatively ancient old world deserts, few species of a much richer ungulate fauna have evolved to become independent of surface water. Therefore we ought not expect it here, this soon and with this taxon, which has not achieved independence from water in the old world either.

A curious observation I have noted over the years is that those most vehemently opposed to water developments are first in line to extol the virtues of, and protect from harm, a "natural water". I submit the biggest difference between one of our created tinajas and a natural one as being merely the visual result and the time line. Water is a naturally occurring substance. I suggest it is illogical to label water as "artificial" or "unnatural".

For those who have persistent doubts and concern about possible "ecosystem impacts," I suggest they rise to the challenge. They should get out of their refrigerated offices and away from their computers, in the summer, and closely observe the system, collect the data, and present their results and conclusions. It is too meager a response to remain in the cool truck or office and muse "but what ifs", while our desert is being ever encroached, fragmented, and degraded. This ecosystem is under siege from all sides, and too often, from below (groundwater pumping) and above (military impacts).

The most ardent critics of water developments generally lose their "leave nature alone" consistency when queried; Is it also wrong for managers to alter "death traps" from being able to slowly starve or drown their hapless victims?

Lee (Lee 1996) found desert bighorn sheep were apparently far more abundant in Sonora Mexico than in Arizona. Lee went on to state that these mountains were with few water sources and that there was no water development program in these areas.

Lee's observations have been subsequently quoted by Broyles (Broyles 1995) and Brown (Brown 1997) as evidence for bighorn thriving without water sources. Mendoza (Mendoza 1976), states he had found 5 water holes in these Sonoran Mountains over a period of 6 years. I note these water sources were located in those mountains identified by Lee with the highest numbers of bighorn sheep.

I have utilized the helicopter for the purpose of surveying bighorn and to seek water sources and have found the 2 activities to be nearly exclusive, due to the speed, flight elevation and focal distances involved. We are still finding the occasional tinaja and "slot tank" in Arizona mountains after 20+ years of surveying them. I suggest a number of these sites are also awaiting discovery in the virtually unknown mountains of Mexico.

Lee's paper surprisingly lacks any discussion that these southern and central Sonoran ranges with high bighorn densities are not comparable to Arizona mountains due to the combined effects of frequent fogs that originate in the Gulf of California, and that these ranges are virtually frost free, which allows for a much greater range of succulent warm season plants. I have observed columnar cacti there (Stenocereus, Pachycereus, and Cereus) with fruits present from May through October. Finally, the Mexican monsoon initiates in this area and progressively moves north.

These southern desert bighorn face a substantially shorter early summer drought and a much more predictable summer wet season than do those living in Sonoran mountains along the Arizona border which evidence comparatively low densities of bighorn.

The arguments advanced by Brown (Brown 1997) are that increases in Arizona bighorn populations can be attributed to transplant efforts and reductions in livestock grazing. While there is undoubtedly some merit to this argument we will unlikely be able to separate these effects. Brown undermines his own opinion though in stating that Arizona densities are similar to those observed in Northern Sonora where neither reductions in grazing nor transplants have been implemented. Brown further attempts to buttress his argument by referencing the surveys of the populations of bighorn sheep in central Sonora, and intimates they are thriving independently of water sources.

I disagree and reference Mendoza (Mendoza 1976) to assert this population does have access to water and again point out that this population is not subjected to the same summer climate nor utilizing the same type of floral community. Brown makes a good case that we are increasing Arizona desert bighorn sheep populations in the statistics he provides where the Arizona bighorn harvest has increased by a factor of 3 since the 1960’s. This despite substantial increases in human pressures and continued degrading activities to some of their habitat.

Regardless of the direction of overall population estimates and trends, I assert in order to identify and better isolate the mechanisms that underlie the biological dependence of bighorn to water, one must look at those waters, natural as well as manmade, that are situated in undisturbed situations. Where livestock, burro, fire suppression, and other undue human perturbations, do not diffuse the results. In these sites, the seasonal importance of water sources is repeatedly and resoundingly demonstrated by healthy thriving populations that exhibit stability over time.

## CONCLUSION

Since the beginning of the last century, it has been postulated that desert ungulates ranging from cattle, bura deer, bighorn sheep, peccaries, and desert pronghorn were able to persist in the desert without drinking water. Research has progressively demonstrated this is not true for cattle, peccaries, and the bura deer. There is an adequate and ever growing body of evidence that desert bighorn sheep also require free water. Recently, Sonoran pronghorn have been documented to use surface waters, telemetry studies indicate they move in summer toward areas containing water sources. The trend has been that the longer and harder we look, the more evidence we find indicating the benefits of free water to desert ungulates, and a concomitant erosion of support for the earlier speculations. This trend can be expected to continue.

The recent impact by humans on bighorn has been as thorough as it was ruthless. Global warming appears to be resulting in an increasingly arid Southwest. Groundwater tables have been lowered resulting in springs going dry. Tamarisk (Tamarisk spp.) has closed access to other springs as well as many areas where mountains joined the rivers. Homesteaders and miners shot bighorn and other wildlife as it was seen. Their goats and other livestock brought new exotic diseases to bighorn. The desert plains were (and continue to be) repeatedly severely overgrazed, fences, highways, railroads, and canals were built further fragmenting metapopulations. In extensive desert areas where there have not been any water development programs such as the Tohono O'odham Indian Nation in Arizona, there are vast mountainous areas nearly devoid of bighorn sheep (Brown 1972).

Today desert bighorn are making an incremental comeback from these impacts. In the few areas where there aren't excessive competition and disease issues from equines and livestock, brush encroachment due to fire suppression, and only in those areas with adequate water sources, do we observe them making a recovery.

The importance of water sources in arid lands to man and desert bighorn has been documented as petroglyphs on the rocks for thousands of years. Ancient agrarian cultures are well documented in altering water distribution. Members of these same tribes also functioned as hunter gatherers, the importance of natural waters is evidenced by their rock blinds, grinding holes, and rock art often depicting bighorn, at most springs and tinajas.

The Coahuilla indians of SE California are reported (Wharton 1907) to have dug depressions over 7.5 m (25') deep. They called these te'ma-ka'-wo-mal-em (possibly the origin of the word tinaja). Other indigenous people likely indulged in water development activities such as placing boulders in tinajas for steps, diverting and storing runoff with earthen dams, and cleaning out accumulated sediments. Water developments and their modifications can be viewed as another natural process in arid ecosystems.

Bighorn sheep affirm the value of water sources when they use them. They have to balance the potential negatives; disease, predation, water quality, etc. with the known positives; to live longer and possibly reproduce. When they have the opportunity, they overwhelmingly choose to re-hydrate.

If we are wrong in our water development efforts, if we are not successfully replicating natural features and processes, then the corrective action (facility removal), is straightforward and simple. Honeybees die, bighorns and other native ungulate populations disappear from some ranges and cycle widely in others. My point is that in one perhaps two dry summers, we could be back to where we were; a time when desert bighorn were critically threatened. While fantasists dream of a return to the ecological conditions that occurred at the time of settlement. Such a scenario is not on the foreseeable horizon. Therefore we carry on doing the best resource management we can, given the political environment we exist in, the knowledge we have, and the human resources available to us. Protecting, and enhancing what is left of our still wonderful public lands and resources.

## MANAGEMENT RECOMMENDATIONS

- Desert bighorn sheep managers should continue to enhance & provide water sources to populations below 1 - 2 adult sheep/sq. km (3 to 5 sheep/sq. mi). These developments should be placed in occupied or suitable habitat exhibiting lightly used floral resources. The distance between water sources should be ideally 5 km (3 mi) in contiguous habitat. Herd units of desert bighorn should not be restricted to one water source in order to reduce the consequence of a system failure being detected too late, and reduce the effectiveness of pumas hunting bighorn at a particular water source.

- In order to further the recovery of desert bighorn sheep, water developments will need to be developed and redeveloped in wilderness areas. These must be designed and constructed in such a manner as to minimize their visual signature and minimize the need for future motorized maintenance. Wilderness managers should be cognizant that these waters must be built or re-developed correctly. Decisions that restrict or limit the activity in order to seek a lesser initial intrusion too often have proven to result in repeated intrusions and/or bighorn losses over time. Nothing in the Wilderness Act of 1964 or the Arizona Desert Wilderness Act of 1990 prohibits the construction or maintenance of water developments within wilderness areas provided they meet the tests for necessity (which this paper makes abundantly clear) and are facilitated by application of minimum tool.

- Bighorn waters should be designed (tinajas, passive systems with walk in troughs, aerial markers for closed tanks) so that they can be monitored primarily via fixed wing aircraft. They should be built to the highest engineering and construction standards (Gunn 1998) with the primary objective of providing water for 12–24 months without recharge, and minimal expected maintenance for 25-50 years. The unfortunate recent failure incidents underscore the need for proper design and timely monitoring.

- Critical bighorn waters should be identified and site specific, inter-agency water hauling operational plans put in place, so that water hauling activities can be initiated rapidly if they become necessary. These waters should also be evaluated for their re-development needs. Interim modifications such as utilizing remote sensing technology (Hill 1999) should be employed.

- Intensive monitoring should be instituted after dieoffs at critical waters to document the effect and eventual recovery of the population. Subsequent surveys should separate the area within 5 - 8 km of the dry water source, and not pool the observations with adjacent areas. Monitoring and other records should be maintained in a database to facilitate future analysis.

- Agency Directors should seek to establish an inter-agency goal to eliminate the current annual loss of native ungulates due to critical waters being allowed to go dry. Annually, we are losing ungulates due to dry water developments. These losses occur at critical (sole source) waters and elsewhere as individuals are struck on highways, drown in canals, or are poached in agricultural fields, while they are seeking water. This goal would necessitate the activity of monitoring and modeling water loss rates at wildlife waters be designated as a very high priority for field personnel (perhaps a department wide effort) during the summer period. It should be anticipated that additional personnel & volunteers from outside the affected sectors would be routinely requested for support as is currently done with other surveys and hunt patrols.

The goal to eliminate current annual summer losses of native ungulates due to dry waters would be facilitated by;

1) Standardized inspection and reporting procedures.

2) Efficient cultivation of and utilization of volunteers.

3) Use of short term contractual services.

4) Building predictive water loss models for each critical water development. These models would document the value of the facility through time and ultimately reduce the need for intensive monitoring.

These models would be valuable assets for future indexing as new survey methodologies are developed. They may in fact become the future census method.

- Prior to initiating research efforts that remove water sources, studies should be initiated on any robust desert bighorn populations thought to be living largely independent of water. The initial parameters to be studied should include population structure and productivity. These data should then be compared to adjacent managed populations.

- Private bighorn and other wildlife advocacy groups should remain vigilant to insure that the state wildlife agency leadership address bighorn herd management needs and concerns to the leadership of the land management agencies. It has been, and will continue to be less effective and duplicative to force each local work unit to establish individual decisions on each and every water development action. There needs to be an understanding of roles and authorities and then a commensurate level of trust as the agencies perform their missions. Wildlife advocacy groups should be willing to request the elected leadership become involved when agency leaders abrogate their duty to establish these cooperative working environments.

**Figure 1**

Mature ram found dead on 8/6/00 at AGFD unit #933
Below; same ram (head was salvaged earlier) 56 days later.

**Figure 1.1**

Mature bura found dead on 8/6/00 at AGFD unit #933
Below; same buck 56 days later.

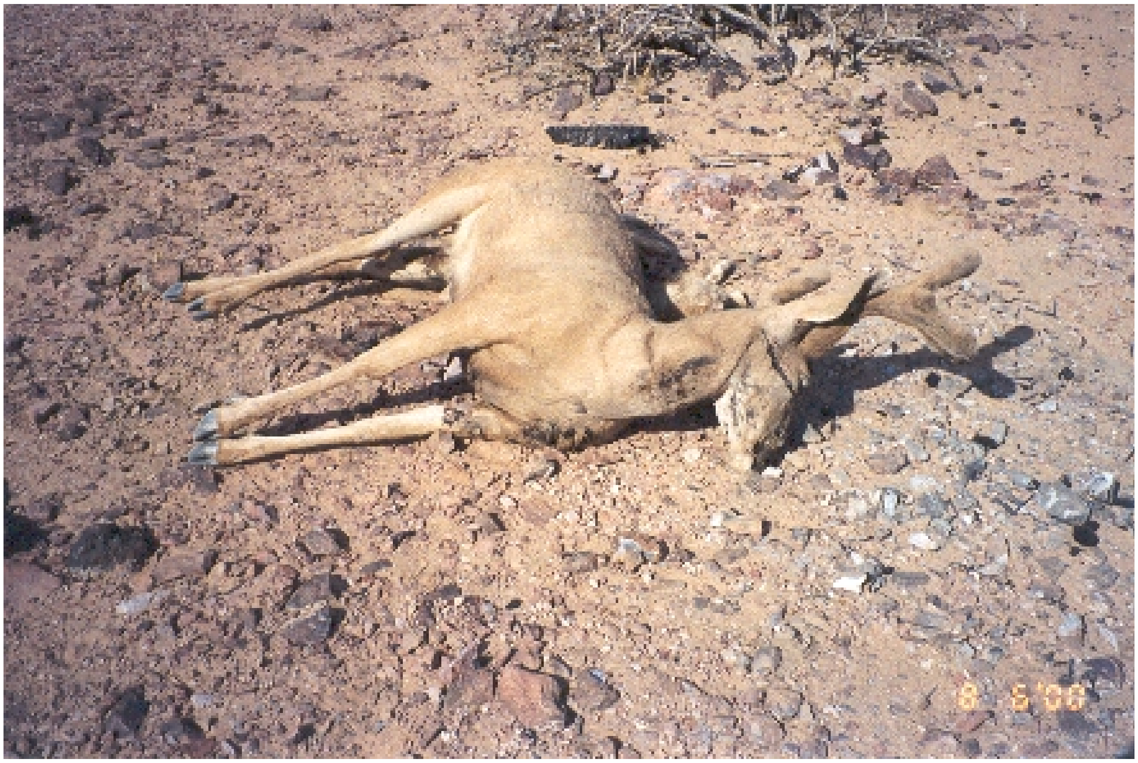

**Figure 1.2**

Bighorn and bura deer found inside storage tank on 8/6/00 at AGFD unit #933
Below: ewes drinking prior to release.

**Figure 1.3**

Saguaros evidencing recent use by bighorn approx. .75 km NW of AGFD unit #933


**Figure 1.4**

Area view of AGFD unit #933
Below; View to South, nearest alternative water source is between the 2 highest points on the skyline, approx. 12 km (7.5) mi) away. Higher terrain leading to the South is just left of this view.


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